JPRS-USB-86-001

19 February 1986

USSR Report

SPACE BIOLOGY AND AEROSPACE MEDICINE

Vol 19, No 6,

November-December 1985

JPRS-USB-86-001

19 February 1986

USSR Report

SPACE BIOLOGY AND AEROSPACE MEDICINE

Vol 19, No 6,

November-December 1985

FBIS FOREIGN BROADCAST INFORMATION SERVICE

NOTE

JPRS publications contain information primarily from foreign newspapers, periodicals and books, but also from news agency transmissions and broadcasts. Materials from foreign-language sources are translated; those from English-language sources are transcribed or reprinted, with the original phrasing and other characteristics retained.

Headlines, editorial reports, and material enclosed in brackets [] are supplied by JPRS. Processing indicators such as [Text] or [Excerpt] in the first line of each item, or following the last line of a brief, indicate how the original information was processed. Where no processing indicator is given, the information was summarized or extracted.

Unfamiliar names rendered phonetically or transliterated are enclosed in parentheses. Words or names preceded by a question mark and enclosed in parentheses were not clear in the original but have been supplied as appropriate in context. Other unattributed parenthetical notes within the body of an item originate with the source. Times within items are as given by source.

The contents of this publication in no way represent the policies, views or attitudes of the U.S. Government.

PROCUREMENT OF PUBLICATIONS

JPRS publications may be ordered from the National Technical Information Service (NTIS), Springfield, Virginia 22161. In ordering, it is recommended that the JPRS number, title, date and author, if applicable, of publication be cited.

Current JPRS publications are announced in Government Reports Announcements issued semimonthly by the NTIS, and are listed in the Monthly Catalog of U.S. Government Publications issued by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Correspondence pertaining to matters other than procurement may be addressed to Joint Publications Research Service, 1000 North Glebe Road, Arlington, Virginia 22201.

JPRS-USB-86-001

19 February 1986

USSR REPORT

SPACE BIOLOGY AND AEROSPACE MEDICINE

Vol. 19, No. 6, November-December 1985

Translation of the Russian-language bimonthly journal KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA published in Moscow by Izdatel'stvo "Meditsina"

CONTENTS

PUBLICATION DATA

English title	:	SPACE BIOLOGY AND AEROSPACE MEDICINE Vol 19, No 6, Nov-Dec 85
Russian title	:	KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA
Editor	:	O. G. Gazenko
Publishing house	:	Meditsina
Place of publication	:	Moscow
Date of publication	:	November-December 1985
Signed to press	:	24 October 1985
Copies	:	1428
COPYRIGHT	:	"Kosmicheskaya biologiya i aviakosmicheskaya meditsina", 1985

SURVEYS

UDC: 629.78.042:614.37:678

PROBLEM OF COMBINED TOXICOLOGICAL AND HYGIENIC EVALUATION OF POLYMER CONSTRUCTION MATERIALS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 17 Sep 84) pp 4-11

[Article by G. I. Solomin]

[English abstract from source] This review surveys the data on environmental effects upon toxicity of polymers used in the interior of manned enclosures. An integrated approach to the assessment of polymer safety is described which takes into consideration space flight effects on the migration of volatile chemicals into the cabin and which includes hygienic monitoring of them at different stages of spacecraft production. Hygienic requirements for the evaluation of nonmetallic materials are given.

[Text] The high physicochemical, mechanical and operational properties of polymers are the reasons for their extensive use in the most varied sectors of the national economy and in everyday life. Many polymers are also used in the manufacture of spacecraft. Several hundred nonmetal materials are used only to outfit the manned compartments of spacecraft: structural parts, ornamental and finishing coverings, varnishes and paints, enamel, bases, sealers, compounds, rubber and others [13]. Many synthetic materials are contained in the onboard apparatus and equipment used for different purposes, items of personal hygiene and clothing of cosmonauts.

The wide use of polymers in spacecraft engineering (in particular, for the equipment in pressurized manned cabins) raises the task of intensifying hygienic monitoring of their use because they present a potential hazard to human health. A great flaw of polymers of hygienic and toxicological significance is their capacity to emit into the environment chemicals that are harmful to human health. In addition, accumulation of charges of static electricity on the surface of materials, capacity to stimulate development of microorganisms and irritate the integument are among the adverse consequences. Dust formed from polymers may reach the respiratory tract and cause inflammatory reactions. Finally, many polymers (particularly when heated) have an unpleasant odor and, consequently, create discomfort in the cabin and affect well-being.

The potential hazard of polymers depends on factors such as chemical structure, toxicity of original raw materials and diverse additives required for the

polymerization process and to impart the specified operating properties to the materials. The technology of manufacturing these materials and time at which they are used in construction are very important. As a rule, materials manufactured less than 3 months before use emit significant amounts of gases. The toxicity of polymers is attributable to a large extent to operating conditions, which affect the process and kinetics of emission of volatile chemical gases.

Some amount of experimental data has been accumulated to date indicating the effect of factors inherent in manned compartments of spacecraft on the level of migration of chemicals from polymers and their toxicity. This report is a survey of such studies.

The level of migration of chemicals from polymers depends on many factors, among which the degree of destruction under the effect of physical, chemical, mechanical and biological causes is in first place. Among the physical factors, which should single out, first of all, temperature, which often determines the qualitative and quantitative composition of emitted gas products. For this reason, it is a priority objective of hygienic investigations to examine the effect of temperature on nonmetal materials in pressurized compartments. The importance of such research is also attributable to the possibility of accidents. These studies make it possible to perform a hygienic evaluation of tested samples and select the best for use and, in some instances, to recommend methods of lowering gas emissions.

The influence of temperature on gas emission from polymers is generally the same: the intensity of emission of toxic substances and their concentrations in air are directly related to this factor. It has been established experimentally that the number of substances emitted is governed by an exponential law in the temperature range of 10 to 100°C [2, 3]. Further elevation of temperature is associated, for most materials, with partial destruction, and there is drastic increase in concentrations of low-molecular compounds in the gas complex.

Knowledge of the mechanism of gas emission from polymers has much practical importance. It permits forecasting the concentrations of volatile substances at any specified temperature and, consequently, to furnish a toxicological evaluation for concrete conditions of their use. Work dealing with investigation of the process of gas emission as a function of time and temperature made it possible to develop high-speed methods of sanitary and chemical examination of heat-resistant polymer paint, varnish and textiles. This reduced the time required for hygienic evaluation of new materials at the stage of their laboratory investigation (from 7-15 days to 1-3.3 h) [6] and to determine the mean value of the temperature conversion factor (increase in gas emission with 10°C rise in temperature), which turned out to equal 1.5.

The concentrations of volatile chemicals emitted from polymers also depend on air velocity above them [1]. This is a linear function; however, it persists only for so long as gas emission is attributable to diffusion. With increase in velocity of air flow above the polymer there is increase in concentrations of volatile chemicals migrating from it. Such a pattern was demonstrated in an experimental test at air velocities of up to 0.4 m/s. A 4-5-fold increase

in concentration has been demonstrated for volatile substances such as ammonia and formaldehyde, which are most often identified in complexes of gases; their levels in air above the polymer are the most frequent restrictive factor in offering recommendations about using a polymer under actual conditions [17].

Several investigations demonstrated the influence of water vapor content of air on the process of gas emission by polymers. At relatively low heating temperatures (up to 80°C), an increase in relative humidity can be associated with increase in concentrations of some gas emission products. At the same time, a decline was observed in levels of agents such as carbon monoxide and styrene [22].

Experimental data concerning the effect on polymer gas emission of altered atmospheric pressure and gas composition of air are of considerable relevance to setting hygienic standards [14]. A total of 57 samples of materials were submitted to laboratory examination at normal and low, 450 mm Hg, pressure in a gas environment containing 21 and 40% oxygen at temperatures of 40 and 105°C. The results of sanitary and chemical testing of each sample separately revealed that, depending on pressure level, emission of gases by the tested polymers can be arbitrarily divided into several groups. In 10% of the samples, there was no change in gas emission at low pressure, in 60% it increased by about 2 times and in 30% by more than 2 times. When pressure was lowered, there was maximum increase in gas emission from materials with a large amount of volatile substances (glue, paints and varnishes, enamels) and well-developed surface (fabric, film). It should be stressed that the demonstrated changes in gas emission pertained only to a few volatile products, and they were not typical of all chemicals found in the gas complex.

Thus, the results of sanitary chemical studies indicate that lowering general pressure in a sealed compartment to 450 mm Hg leads, in most cases, to an increase by a mean of 1.4 ± 0.15 times in concentrations of volatile substances, as compared to levels at normal pressure. The differences demonstrated in the experiments in intensity of gas emission are apparently related to the influence of the set of factors that determine the gas-emitting process, the significance of which is dissimilarly manifested in different polymers. They include, in particular, physicochemical properties and structure of the polymers, coefficients of diffusion of volatile substances and their levels in materials.

Recommendations to lower gas levels in different types of polymers (paint and varnish, enamel and fabric) were based on the results of testing the effect of altered barometric pressure on the gas-emitting process.

Studies were made of the effect on gas emission of vibration, mechanical loads, radiation and constant magnetic field [5, 10, 12, 24, 27]. In a number of instances, intensification of migration of volatile chemicals was found. However, the degree of increase in gas level depends on the intensity of effect of the factor, structure of polymer, the low-molecular compounds it contains that are not subject to polymerization. As a rule, the following solvents were identified in the complex of gases: acetone, acetates, alcohols and aldehydes. At the same time, it should be noted that high levels of the mentioned factors could lead to appearance in the atmosphere of products of destruction of polymers.

Information about the data of manufacture of a material that is used, how long man is in contact with this material and how much of it is contained in an object (in kg/m^3, in m^2/m^3) is important to hygienic monitoring of safe use of polymers. Many authors have conducted studies in this direction [3, 4, 7, 18, 25]. It has been shown that the most intensive emission of volatile substances from a polymer occurs within the first few months after it was manufactured, after which there is stabilization of gas emission followed by decline of concentrations of volatile substances. This conclusion was confirmed by analysis of data pertaining to the air environment of manned compartments in the course of operating spacecraft [13, 28].

N. R. Shepelskaya [20] derived equations for different samples of paints and varnishes, which make it possible to predict the amount of emitted components as a function of data of manufacture of the material. If the allowable level of emission is known, it is possible to similarly estimate the time after which the concentrations of migrating low-molecular compounds reach this level.

The results of our investigations and data in the literature concerning the dynamics of gas emission enabled us to conclude that there is drastic decline in emission of volatile substances in the first 2-3 months, followed by some stabilization of the process and then slow (by 10-15%/month) decline of concentration. This conclusion served as grounds for setting hygienic requirements of nonmetal materials, according to which only samples aged for at least 4 months (time from manufacture of material to its use in an object) are recommended for equipment in spacecraft cabins.

The specific distinction of sealed compartments is that they are highly "saturated" with polymers. Thus, total "saturation" could reach tens of kg/m^3, whereas the quantity of different materials fluctuates over a rather wide range, from thousandths of a kilogram or square meter to several kilograms. The authors of these studies observe that, with increase in "saturation," one finds an increase in concentrations of chemicals in ambient air; however, this is not a linear function [20]. In view of the difficulty of defining this function, laboratory tests should be done using different quantities of a sample.

Thus, factors inherent to living conditions in the pressurized compartment of spacecraft influence the process of emission of volatile substances from polymers. These factors must be taken into consideration in making a toxicological evaluation of materials to be used to equip such compartments.

In the case where the gas emission process is a function of many factors, the role of bench and mockup tests grows significantly. It becomes possible to develop and maintain for a long time the factors that exist under actual conditions, and to use the appropriate life-support equipment. The reproducibility of all these parameters makes it possible to obtain objective information about the extent and nature of emission of toxic substances from synthetic materials, the patterns of formation of the gas and air environment in pressurized areas with concurrent exposure to all ambient factors.

At the present time, a system has been developed and introduced into practice for hygienic monitoring of safe use of nonmetal materials [14]. The system provides for the following measures:

Preliminary testing of synthetic materials used in specific objects for toxicity of compounds. These materials are not subject to sanitary chemical testing (samples containing agents with marked allergenic, carcinogenic, mutagenic or embryotropic action).

Laboratory tests on different samples of materials, the results of which make it possible to screen samples that do not emit gases or materials with minimal gas emission for use.

Bench testing of materials contained in apparatus or equipment under the conditions that these items are operated.

Mockup tests of the aggregate of nonmetal materials used under conditions that are as close as possible to actual operation.

Field tests, which permit determination of the effect of nonmetal materials on formation of the gas atmosphere in a pressurized compartment during operation of the spacecraft.

Sanitary chemical studies that are conducted at all stages of testing play a large part in the system of hygienic monitoring of use of polymers. In these studies, gas chromatography and mass spectrometry must be used. Sanitary chemical analyses make it possible to obtain a toxicological conclusion without labor-consuming experiments. In this case, the data on gas emission are compared to the appropriate hygienic standards (MPC [maximum permissible concentration]). Consideration is given to the nature of the combined effect of the entire set of volatile substances by demonstrating compounds with action in the same direction. Toxicological experiments are performed on animals in the case where the volatile substances contain compounds that could not be identified, or else for which there are no hygienic standards.

The results of sanitary chemical testing of more than 1000 samples of nonmetal materials (at the stage of laboratory tests) made it possible to identify chemicals emitted by nonmetal construction materials. They include low-molecular compounds, such as alcohols, aldehydes, ketones, acetates, aromatic hydrocarbons and others. In all, about 80 chemicals were identified. It was found that paints and varnishes emit the most gases (up to 80% of all gas emission by materials). The concentrations of these substances are low, and at temperatures of up to 40°C they are in the range of 0.01-1.0 mg/m^3, i.e., they are below the hygienic standards worked out for the atmosphere of sealed areas. In addition, it was experimentally demonstrated that most of the nonmetal materials studied, regardless of their chemical nature, emit different amounts of carbon monoxide and dioxide, hydrocarbons of the methane class and formaldehyde. The concentrations of formaldehyde are often an indicator, on the basis of which materials are rejected. The low MPC of formaldehyde is related to the possibility of sensitization of the human body [9]. The detected low-molecular compounds are referable to solvents that are used in the manufacture of polymers.

Some patterns in the process of gas emission of materials when several are present were demonstrated as a result of bench and, particularly, mockup tests. Thus, it was established that the levels of chemicals emitted by a

group of materials do not reach the total concentrations obtained under laboratory conditions when testing individual materials, whereas some constituents were not demonstrable at all [16]. Evidently, this phenomenon can be attributed to the fact that some polymers not only emit chemicals, but absorb them. The mutual spatial location of materials and interior of a sealed compartment also contributes to this.

A distinction of the biological effect of chemicals emitted from polymers is that, on the level of low concentrations, they have a nonspecific action and can elicit mostly a strain on compensatory and defense reactions of man. Their capacity to accumulate and elicit allergic diseases presents a special hazard. Some chemicals used in the manufacture of polymers have specific action. For example, changes in processes of bone marrow cell division under the influence of ethylenimine, propylene oxide, dipropylamine and a few other compounds have been demonstrated [11]. Data were obtained on the Drosophila fly indicative of high genetic activity of isopropylbenzene hydroperoxide [21]. Dioxane, chloroprene, nitrofuran and its derivatives have specific gonadotropic, embryotropic and genetic action [8]. It was shown that these specific disturbances may occur long before appearance of signs of poisoning. Data in occupational pathology have much information about the nature of the deleterious effects of gas emission products of polymers.

All of the foregoing indicates that a hygienic evaluation of polymers must be made not only at the stage of developing an item, but at the stage of developing the formula for a polymer. This requirement is due to the fact that many chemicals with the most diverse spectra of biological activity may be used as raw material and additives in the process of polymer manufacture. For example, both highly toxic *o*-tricresylphosphate and biologically inert vaseline oil are used as plasticizers, whereas virtually nontoxic derivatives of benzophenone and thiophenes, as well as highly toxic esters of phosphoric acids are used as stabilizers. Among monomers, one encounters both compounds that have little biological activity, such as olefins, and toxic ones, such as diizocyanates, hexamethylenediamine and isopropylbenzene hydroperoxide.

An integrated approach to the question of safe use of polymers implies that studies are pursued, not only when the item operates in the regular mode, but in the case of a possible emergency situation. Overheating and combustion of materials, which occur as a result of malfunction of onboard systems can be the cause of emergency situations. For this reason, investigation of the extent and nature of toxic effects of products of thermal-oxidative destruction (PTOD) of materials is an important toxicological aspect of the problem of using synthetic materials.

The degree of hazard increases if combustion of materials occurs in a sealed area of limited size, since accumulation of PTOD to toxic levels occurs extremely rapidly. In addition, an oxygen shortage occurs. And the feasibility of immediate exit from the dangerous zone is limited. All this indicates that polymers present the greatest hazard in case of fire.

Polymers can be divided into three groups according to type of thermal destruction: polymers that are entirely destroyed with a break in the main chain; polymers, in which there is detachment of side fragments during destruction, which yield volatile gas products and a coke residue; cross-linked polymers,

which emit nonvolatile products and much coke. Materials are classified according to combustibility: nonflammable (polytetrafluoroethylene), poorly flammable (melamine-urea-formaldehydes, polyvinylchlorides) and readily flammable (polyethylene, polystyrene plastics, cellulose esters).

The gas and aerosol mixtures formed during combustion constitute complicated and toxicologically insufficiently studied complexes, the composition of which is determined primarily by the formula for a material and conditions of its combustion [15, 19, 23, 26]. The toxicity of these gas complexes is attributable to the combined effect of the different chemicals.

The main directions of research on safe use of polymers with reference to investigation of toxic properties of their PTOD have been as follows up to this time:

To obtain base data about comparative toxicity of different samples of materials in order to screen nonflammable and mildly toxic plastics.

To develop a unified method of investigation toxicity of PTOD of materials that would adequately reflect the specific conditions of pressurized compartments.

To develop and scientifically validate guidelines and criteria for toxicological evaluation of materials according to the PTOD toxicity indicator (maximum allowable concentrations of PTOD in case of fire, when use of individual protective gear is difficult, but it is necessary to fulfill a planned program).

To investigate the combined effect of combustion products of materials and elaborate methodological approaches to predicting their toxicity.

Analysis of the results of our studies and data in the literature pertaining to investigation of toxicity of PTOD of polymers of different classes enabled us to draw the following conclusions.

1. A general conclusion is that carbon monoxide and dioxide are formed upon combustion and thermal decomposition of synthetic materials. The levels of these gases in air are closely related to the amount of incoming air. When it increases, there is increase in formed carbon dioxide, and when it decreases, there is increase in carbon monoxide level.

2. When plastics are heated, in addition to carbon monoxide and dioxide, there is formation of specific toxic gases, depending on the formula for the polymer.

3. When chlorine-containing materials are heated, there is formation of hydrogen chloride. And, regardless of temperature and amount of incoming air, virtually all of the chlorine is contained in hydrogen chloride. There are microquantities of chlorine in free form and carbon oxychloride (phosgene).

4. Heating of nitrogen-containing materials is associated with discharge of hydrogen cyanide and ammonia, the amounts of which increase with rise in temperature and increased shortage of air.

5. There is formation of hydrogen fluoride and other fluorine compounds upon combustion and thermal breakdown of fluorine-containing materials.

6. When polymers are exposed to relatively low temperatures (70-120°C) and a shortage of air, there is formation of the corresponding monomers.

7. Carbon monoxide, cyanogen and fluorine compounds, ammonia and formaldehyde present the greatest toxic hazard. In essence these agents determine the symptomatology of poisoning. Their qualitative and quantitative identification is mandatory in order to predict the condition of the atmosphere and health status of crew members.

8. The quantity of a polymer that elicits 50% animal death ranges from 10 to 150 g/m^3 for different classes of polymers.

9. Enhancement of the toxic effect of individual chemicals is observed under the combined effect of PTOD.

Experimental studies of PTOD toxicity revealed that, in case of fire, the main hazard arises due to inhalation of toxic agents by man.

Hygienic regulation of levels of products of polymer gas emission into the atmosphere of inhabited compartments of manned spacecraft is an important aspect of the integrated approach to the problem of safe use of polymers. The experimental approach and rapid investigative methods are used to elaborate and scientifically validate hygienic standards.

The investigations should include a series of animal experiments in order to define the parameters of acute toxicity following the system adopted in industrial toxicology, as well as a 4-month continuous, round the clock experiment in order to demonstrate the chronic effect of tested gases when they are inhaled. Studies are made of behavior of the toxic agent in the body.

The rapid methods of setting MPC [maximum permissible concentrations] of chemicals are based on correlation analysis, which showed close links between MPC in pressurized compartments and such indicators as MPC of gas in work zone air, its median lethal concentration in animals, range of biological effect of an agent, threshold of chronic effect in the case of intermittent inhalation (the coefficients of correlation are +0.95, +0.92, +0.87 and +0.86, respectively). Special formulas have been proposed for making these estimates. It should be noted that there has not been sufficient exploration of questions of setting hygienic standards for toxic agents in the air of sealed compartments, and they require special consideration.

Thus, the integrated approach to the problem of safe use of polymers in manned compartments of spacecraft includes hygienic monitoring of their use at all stages of construction of the crafts and during industrial manufacture of polymers, elaboration of criteria for evaluating them, investigation of the effects of spaceflight factors on the process of migration of volatile chemicals.

BIBLIOGRAPHY

1. Bartenev, V. D. and Ryabikova, V. I., in "Institut mediko-biologicheskikh problem. Nauch. konf. molodykh uchenykh. 2-ya. Materialy" [Proceedings of 2d Scientific Conference of Young Scientists of the Institute of Biomedical Problems], Moscow, 1967, pp 23-24.

2. Bokov, A. N., Nelasova, L. I. and Nelasov, Yu. I., in "Gigiyena i toksikologiya polimernykh stroitel'nykh materialov i nekotorykh khimicheskikh veshchestv" [Hygiene and Toxicology of Polymer Building Materials and Some Chemicals], Rostov-on-Don, 1968, Vyp 1, pp 109-133.

3. Bokov, A. N., in "Gigiyena i toksikologiya vysokomolekulyarnykh soyedineniy i khimicheskogo syrya, ispolzuyemogo dlya ikh sinteza" [Hygiene and Toxicology of High-Molecular Compounds and Chemical Raw Materials Used in Their Synthesis], Leningrad, 1969, pp 68-69.

4. Gorshunova, E. I., Shirskaya, V. A. and Chukhno, E. I., GIG. TRUDA, 1971, No 1, pp 59-62.

5. Guryeva, L. I., Vasenin, V. M. and Golovteyeva, A. A., in "Vliyaniye vibratsiy na organizm cheloveka i problemy vibrozashchity" [Effect of Vibration on Man and Problems of Protection Against Vibration], Moscow, 1974, pp 355-361.

6. Demchenko, Ye. A., Yablochkin, V. D. and Solomin, G. I., GIG. I SAN., 1978, No 4, pp 75-78.

7. Dvoskin, Ya. G., Demchenko, F. V. and Lakshina, A. V., in "Materialy nauchnykh rabot po voprosam gigiyeny vodnogo transporta" [Results of Scientific Research on Hygiene of Marine Transport], Moscow, 1966, pp 95-96.

8. Zaugolnikov, S. D., Khaslavskaya, S. L. and Sukhov, Yu. Z., in "Gigiyena i toksikologiya vysokomolekulyarnykh soyedineniy i khimicheskogo syrya, ispolzuyemogo dlya ikh sinteza," Leningrad, 1969, pp 14-15.

9. Lazarev, N. V., ed., "Vrednyye veshchestva v promyshlennosti" [Toxic Substances in Industry], 7th ed., Leningrad, 1976, Vol 1, pp 505-509.

10. Nikitina, T. S., Zhuravskaya, Ye. V. and Kuzminskiy, A. S., "Deystviye ioniziruyushchikh izlucheniy na polimery" [Effect of Ionizing Radiation on Polymers], Novosibirsk, 1959, pp 25-26.

11. Sanotskiy, I. V., Fomenko, V. N., Katosova, L. D. et al., in "Gigiyena i toksikologiya vysokomolekulyarnykh soyedineniy i khimicheskogo syrya, ispolzuyemogo dlya ikh sinteza," Leningrad, 1969, pp 10-12.

12. Semenenko, E. I., Myshkovskiy, V. I., Voblikova, V. A. et al., PLAST. MASSY, 1973, No 5, pp 30-32.

13. Solomin, G. I., in "Problemy kosmicheskoy biologii" [Problems of Space Biology], Moscow, 1980, Vol 42, pp 43-67.

14. Solomin, G. I., KOSMICHESKAYA BIOL., 1980, No 2, pp 70-74.

15. Solomin, G. I., Yablochkin, V. D. and Ostasheva, N. Ye., in "Novyye metody gigiyenicheskogo kontrolya za primeneniyem polimerov v narodnom khozyaystve" [New Methods of Hygienic Monitoring of Polymer Use in the National Economy], Kiev, 1981, pp 87-89.

16. Solomin, G. I., Yablochkin, V. D. and Gorshunova, A. I., in "Aviakosmicheskaya meditsina" [Aerospace Medicine], Moscow--Kaluga, 1979, Vol 2, pp 89-90.

17. Sopikov, N. F. and Yablochkin, V. D., in "Aviatsionnaya i kosmicheskaya meditsina" [Aviation and Space Medicine], Moscow, 1969, Vol 3, pp 31-38.

18. Stankevich, D. I., in "Gigiyena primeneniya polimernykh materialov" [Hygiene of Use of Polymers], Kiev, 1976, pp 12-17.

19. Ushakov, V. F., Solomin, G. I., Gorshunova, A. I. et al., in "Goreniye polimerov i sozdaniye ogranichenno goryuchikh materialov" [Combustion of Polymers and Development of Materials With Limited Flammability], Volgograd, 1983, pp 94-95.

20. Shepelskaya, N. R., in "Gigiyena primeneniya polimernykh materialov," Kiev, 1976, pp 42-43.

21. Shkvar, L. A. and Sheftel, V. S., in "Gigiyena i toksikologiya vysokomolekulyarnykh soyedineniy i khimicheskogo syrya, ispolzuyemogo dlya ikh sinteza," Leningrad, 1969, pp 13-14.

22. Yablochkin, V. D., Sopikov, N. F. and Gorshunova, A. I., Ibid, pp 73-74.

23. Balt, G., Weiss, B. and Boether, E., AMER. INDUSTR. HYG. ASS. J., 1970, Vol 31, pp 572-573.

24. Yablochkin, V. D. et al., in "International Congress of Aerospace Medicine, 21st," Munich, 1973, p 15.

25. Yablochkin, V. D., Sopikov, N. F. and Gorshunova, A. I., REV. MED. AERONAUT., 1973, Vol 12, pp 305-308.

26. Michaels, A. S. and Parker, R. B., J. POLYM. SCI., 1959, Vol 41, pp 53-71.

27. "MOL and Apollo Materials Tested," TECHNOL. WEEK, 1967, Vol 20, p 4.

28. "Skylab Life Sciences Symposium. Proceedings," Houston, 1974, Vol 1, pp 157-168.

EXPERIMENTAL AND GENERAL THEORETICAL RESEARCH

UDC: 613.693-07:612.881

SPATIAL ILLUSIONS OF VESTIBULAR GENESIS DURING FLIGHTS IN AIRCRAFT

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 24 Aug 84) pp 11-15

[Article by E. V. Lapayev and O. A. Vorobyev]

[English abstract from source] Vestibular illusions (incidence, pattern, manifestation, negative effect on pilot's activity) that occur in the atmospheric flight were studied. A special questionnaire was used to interview anonymously 484 flying crewmembers. Spatial illusions were detected in 71.1% of the crewmembers; they developed in 50.6% when turns were performed and they were perceived in 76.2% as a false bank. Over 50% (54.3%) of the crewmembers interviewed reported that spatial illusions adversely affected pilot's performance and 3.6% of them indicated that they adversely influenced the flight program as a whole. Spatial illusions can be generated by various factors which should be taken into account in order to improve countermeasures against spatial illusions in the flying personnel.

[Text] Flight personnel may develop spatial illusions (SPI) during night flights, under difficult meteorological conditions and in the clouds, in the genesis of which a rather important role is attributed to the effect of angular and linear accelerations during maneuvering of flight vehicles [3, 4, 9, 11 and others]. Thus, the vast majority (97.3%) of the 67% of the pilots who reported various illusions that they encountered in flight stated that these were false sensations of banking, inverted flight, i.e., vestibular illusions [6].

It is known that SPI not only render a pilot's professional performance more difficult, but could serve as the cause of conditions for flight accidents [10 and others]. All this indicates that it is a pressing task for the practice of aviation medicine to investigate the conditions and factors that lead to onset of SPI (primarily of vestibular genesis) during flight (in order to improve the system of measures to prevent illusions in flight personnel).

Our objective here was to investigate the distinctions of vestibular illusions (incidence, nature, conditions of manifestation, extent of adverse effect on pilot performance) that occur during flights in aircraft. For this purpose, a group of flight personnel submitted to an anonymous interview using a specially developed questionnaire.

Analysis of the answers to this questionnaire revealed that pilots experienced inflight SPI in 71.1% of the cases. Illusions were observed in about the same number of cases in flight personnel referable to different age groups: in 73% of pilots under 25 years of age and 69.9% for the older age group. The results are consistent with data of other authors concerning susceptibility of pilots to SPI, regardless of their flight tenure [16].

Table 1 lists data on the incidence of different types of illusions.

Table 1. Characteristics of SPI occuring in flight

Nature of illusory perceptions	Number of cases, % of subjects		
	pilots under 25 years old	pilots over 25 years old	group total
SPI of vestibular genesis:			
illusion of banking	80.2	73.3	76.2
illusion of inverted flight	9.2	5.8	7.3
seeming rotation, slipping, motion in vertical plane	7.6	4.1	5.6
illusion of horizontal flight (when plane is banking)	-	4.7	2.6
illusion of pitching, diving (dropping forward, back, hovering in straps)	0.7	1.7	1.3
Spatial disorientation	2.3	4.1	3.3
False visual phenomena:			
sensation that the sky is up and down	-	4.0	2.3
illusion of appearance of extraneous objects in the air, wrong estimate of distance	-	1.2	0.7
Time disorientation	-	1.1	0.7

As can be seen in Table 1, mainly illusions of false position of the aircraft in space (among which there is significant prevalence of illusion of banking) occur in flight personnel during flights, while illusory perceptions of motion, including rotation, occur considerably less often. Nevertheless, as shown by analysis of appearance of SPI as a function of different phases of flight, illusory sensations arise the most often when engaged in aerobatics: bank (50.6%), loop (9.3%), zooming (9.3%) and others. The rare incidence of illusion of rotation is most probably attributable to the fact that during aerobatics the angular velocity of the flight vehicle changes according to a close to parabolic law. And with such a function of angular velocity in relation to time no marked postrotatory vestibular reactions occur (particularly if rotation lasts no more than 10 s), which has been confirmed by experimental data obtained with sinusoidal rotatational stimulation of the vestibular system [7].

Analysis of data reflecting the nature and extent of effect of SPI on pilot performance revealed that over half the individuals questioned (54.3%) are convinced of the adverse effect of illusory perceptions on piloting quality.

More subjects reported such an influence in the older age groups: 37.1% of pilots under 25 years of age, 66.7% of those 25-35 years old and 78% of those over 35 years old. This is apparently due to the fact that, with increase in age (and consequently in flight experience), pilots make more use of their own perceptions as noninstrumentation cues about flight mode in order to determine the spatial position of the flight vehicle [1], and they also make flights under more difficult conditions. This is also apparently related to the fact that, with increase in age, flight personnel report more diverse illusory perceptions (see Table 1). The adverse effect of SPI on flying quality is manifested primarily by onset of strain during the period of illusions (17.6% of the responses), longer time required to take instrument readings (8.8%) and, finally, distraction of attention to their own perceptions in order to determine the spatial position of the flight vehicle (2.7%); and in 3.6% of the cases, the pilots reported that SPI have an adverse effect on fulfillment of the flight program.

Subsequent analysis of answers to the questionnaire (Table 2) enabled us to divide the different conditions, under which SPI occur, into three main groups without rigid definition of boundaries between them.

Table 2. Characteristics of flying conditions that lead the most often to SPI

Conditions and elements of flight	Cases of SPI, %
Entering clouds with bank or on a turn	20.0
Flight between or above clouds when their edge is uneven (oblique)	13.4
Unilateral illumination of cabin by sun or moon, drastic change in flying conditions	15.8
During and after aircraft maneuvering	20.8
Flying blind	15.8
Long-term flights	7.5
After changing position in seat	6.7

Thus, we can refer to the 1st group SPI that occur when the pilot tracks external spatial reference points in flight (when natural horizon is not visible). For example, when the pilot views external space when entering clouds at a bank (because of which he sees the outlines of the aircraft canopy at an angle in relation to the forward edge of the clouds), when flying then in the clouds after leveling the flight vehicle he could retain the perception of banking, i.e., there will be an illusion of banking. Consequently, in this case the SPI most probably occurs due to primarily visual and vestibular interaction, since in these flying conditions there is the combined effect of accelerations and optokinetic stimuli that are unrelated to groundbased reference points. Experimental data indicating that illusory perceptions of man's own motions or false position (including illusions of banking) can be induced in the laboratory by means of optokinetic stimulation, without use of accelerations [12, 13 and others], can serve as grounds for this assumption. Moreover, it was established that man's accuracy of orientation in relation to the gravity vertical depends largely on the spatial location of visual coordinates [5, 17 and others]. Finally, it has now been convincingly proven in electrophysiological experiments on animals that the activity of neurons of most vestibular elements is selectively modulated upon presentation of moving visual stimuli [8, 15 and others].

The 2d group (see Table 2) refers to flying conditions, under which SPI occur as a result of mainly the effects of mechanical forces on the pilot during maneuvering of the aircraft when external reference points are not visible (when flying in the clouds, blind, etc.). For this reason, in such cases SPI can be viewed as illusory perceptions generated primarily by stimulation of the vestibular analyzer when the additional visual stimulation by external reference points is wanting to some extent or other.

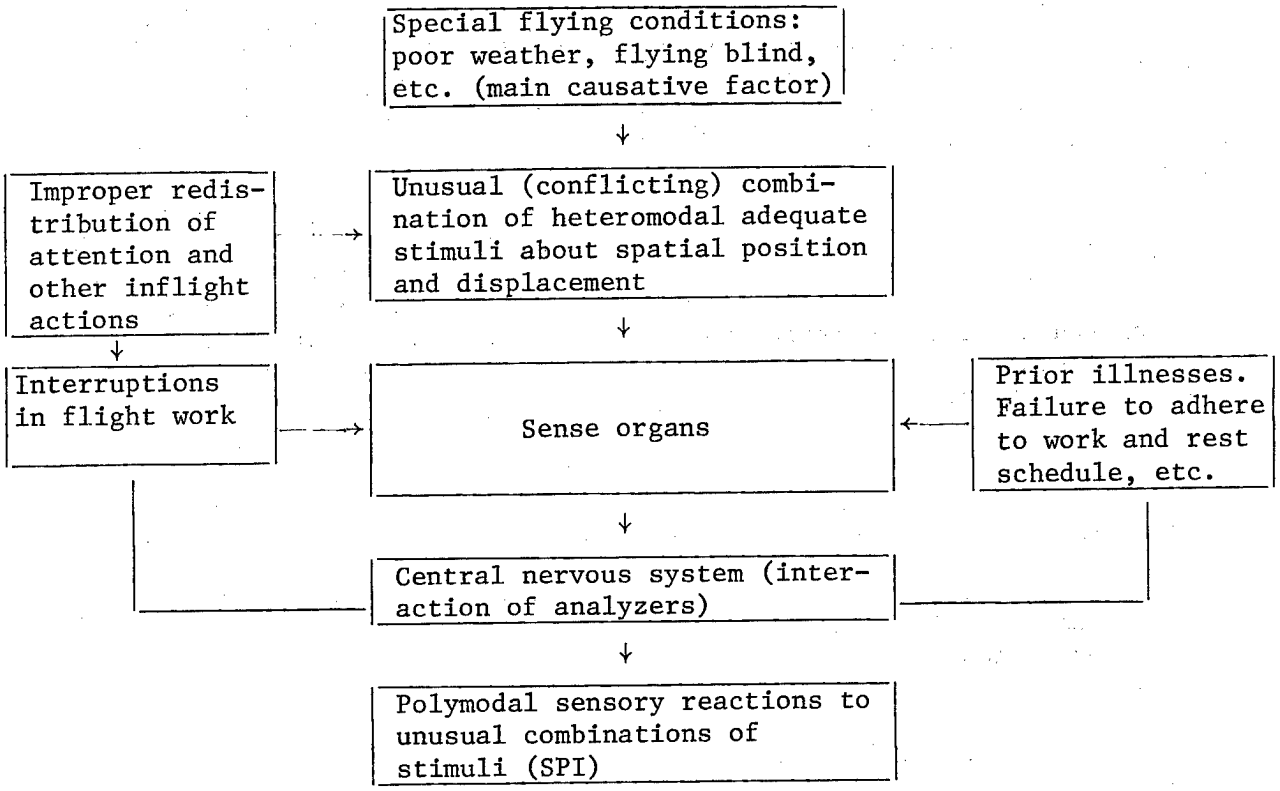
Finally, the 3d group (see Table 2) consists of conditions leading to development of SPI as a result of reactions by the motor analyzer (when an unchanged position is held for a long time, with abrupt movements of the body, etc.), which apparently elicit certain changes in afferent and efferent influences in the statokinetic system of the body as a result of correlation between the motor and vestibular systems [2, 14 and others].

Flight personnel mentioned as the main conditions for onset of SPI (33.3% of the cases) primarily improper distribution of attention on instruments, prolonged distraction from instruments when observing external space in the absence of visible groundbased reference points. Substantial importance was attributed to "rustiness" in flying (23%) and fatigue due to unsatisfactory preflight rest (21.5%). The pilots relate to a lesser extent the onset of illusory perceptions to inflight tension, distrust in instrument readings (8.2%) and morbid states (7.4%).

To sum up the above-mentioned groups of conditions that generate SPI, it should be noted that we can distinguish in each of them the presence of concurrent stimulation of several analyzer systems of perception of motion, as well as appearance of contradictory (conflict) afferentation about the nature of displacement in space. For this reason, it can be assumed that, from the physiological point of view, SPI are adequate polymodal sensory reactions to unusual (not encountered in man's everyday life) combinations of sensory stimuli under the unique conditions of flight, rather than the consequence of impaired interaction of analyzer systems in such situations. The same incidence of SPI in young and experienced pilots is also indicative of the fact that illusory perceptions of vestibular genesis are not due to transient intersensory disturbances.

This hypothesis concerning the possible genesis of SPI implies that different factors play dissimilar roles in generating illusory perceptions, as shown in the Diagram. As can be seen in this diagram, the triggering element in the mechanism of development of SPI is the unusual (conflicting, with regard to nature of displacement or position in space) combination of adequate sensory system stimuli generated by the unique flying conditions as the main causative factor. In addition, it should be stressed that this triggering element of development of SPI is activated under the effect of a number of concomitant (predisposing) factors that determine the distinctive psychophysiological status of the pilot under the special flying conditions. Consequently, when refining the system of measures for prevention of SPI in flight personnel, it is imperative to take into consideration the dissimilar role of different factors in the genesis of these perceptions.

The proposed approach concerning the possible mechanisms of onset of SPI of vestibular genesis during flights in aircraft requires, of course, further



development and, first of all, consideration of such factors as the possibility of conditioned reflex mechanisms of development of illusions, manifestation of individual distinctions in interaction of sensory systems under the effect of dynamic flight factors, correlation with mental states, etc.

BIBLIOGRAPHY

1. Beregovoy, G. T., Zavalova, N. D., Lomov, B. F. et al., "Eksperimentalno-psikhologicheskiye issledovaniya v aviatsii i cosmonavtike" [Experimental Psychological Investigations in Aviation and Astronautics], Moscow, 1978.

2. Granit, R., "Osnovy regulyatsii dvizheniy" [Bases of Control of Movements], Moscow, 1973.

3. Derevyanko, Ye. A., Zhernavkov, V. F., Kuznetsov, V. G. et al., in "Aviatsionnaya i kosmicheskaya meditsina" [Aviation and Space Medicine], Moscow, 1969, Vol 1, pp 178-182.

4. Yemelyanov, M. D. and Kuznetsov, A. G., VESTN. OTORINOLAR., 1962, No 3, pp 63-68.

5. Kurashvili, A. Ye. and Babiyak, V. I., "Fiziologicheskiye funktsii vestibulyarnoy sistemy" [Physiological Functions of the Vestibular System], Leningrad, 1975.

6. Lapayev, E. V., "Functional State of Vestibular Analyzer With Change in Reactivity," doctoral dissertation, Moscow, 1974.

7. Lapayev, E. V. and Vorobyev, O. A., ZHURN. USHN., NOS. I GORL. BOL., 1982, No 2, pp 11-17.

8. Mitkin, A. A., USPEKHI FIZIOL. NAUK, 1982, Vol 13, No 3, pp 56-81.

9. Yuganov, Ye. M. and Zakhmatov, D. M., VOYEN.-MED. ZHURN., 1958, No 4, pp 51-55.

10. Bell, H. and Chonn, S., AEROSPACE MED., 1964, Vol 35, pp 552-560.

11. Blanc, P., MED. AERONAUT. SPAT., 1978, Vol 17, pp 322-324.

12. Brandt, Th., Dichgans, J. and Koenig, E., EXP. BRAIN RES., 1973, Vol 16, pp 476-491.

13. Dichgans, J., Held, R., Young, L. R. et al., SCIENCE, 1972, Vol 178, pp 1217-1219.

14. Gernandt, B. E., EXP. NEUROL., 1968, Vol 20, pp 120-134.

15. Henn, V., Waespe, W. and Buttner, U., EXP. BRAIN RES., 1981, Vol 41, p A25.

16. Peters, R. A., "Dynamics of the Vestibular System and Their Relation to Motion Perception, Spatial Disorientation and Illusions," NASA, CR-1309, Washington, 1969.

17. Witkin, H. A., PSYCHOL. MONOGR., 1949, Vol 63, No 7, pp 1-46.

UDC: 629.78:612.828-053.9]-06:612.766.2

VESTIBULAR FUNCTION IN OLDER INDIVIDUALS SUBMITTED TO ANTIORTHOSTATIC HYPOKINESIA FOR 30 DAYS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 18 Jan 85) pp 15-20

[Article by V. K. Gavrilin and L. N. Zakharova]

[English abstract from source] Vestibular responses of 15 men (aged 42-50) to 30-day head-down tilt (-8°) were investigated. The test subjects showed atherosclerotic symptoms and neurocirculatory dystonia of the hypertensive type. They were exposed to the Fitzgerald-Hallpike caloric test, indirect otolithometry (eye counter-rolling reflex according to the method of successively presented images), and motion sickness according to Bryanov. In the pretest period vestibular changes were seen at the level of labyrinths and central formations (change in the nystagmic pattern, dissociation of the components of the caloric reaction, vestibular asymmetry, negative counter-rolling). During head-down tilt cupular reflexes remained essentially unaltered, except for the asymmetry and enhancement of the sensory and autonomic components of the caloric reaction. The otolith function was modified in all the test subjects. After exposure tolerance to motion sickness was not deteriorated. The time-course variations of the vestibular reactions of the tilted subjects were similar to those seen in young and healthy test subjects. The results of this simulated study suggest that vestibular reactions of crewmembers of the above age group in real space flight should be close to those of the young and healthy crewmembers.

[Text] It is known that hypokinesia, particularly antiorthostatic (AOH), is one of the generally recognized models of some physiological effects of weightlessness [6].

Several authors have observed changes in vestibular function under hypokinetic conditions [8, 14-16, 21]. However, the results of the studies are heterogeneous, and they were obtained mainly from tests on young and healthy subjects. At the same time, it is known that human vestibular function can change substantially with age [10, 26, 29, 31].

Our objective here was to examine the function of the vestibular analyzer and levels of vestibulovegetative stability (VVS) in older subjects with deviations of health status, as well as the effect of 30-day AOH on the functions studied.

Methods

We tested 15 men 42-50 years of age. We found early or moderate signs of atherosclerosis in nine of them (first group) on the basis of the results of a comprehensive clinical and biochemical examination (by an internist, roentgenologist, neurologist, cardiologist, biochemist and others). The diagnosis of vegetovascular dystonia (VVD) of the hypertensive type was made in six cases (second group).

All of the subjects spent 30 days under AOH conditions (bedrest with the head end of the bed tilted down 8° below the horizontal plane). Food intake, hygienic procedures and physiological functions were not associated with a change in AOH position. In the baseline and recovery periods, the subjects were on an unrestricted regimen at the hospital. The studies consisted of three stages: background, AOH and recovery.

They involved taking a history, examination of the ear, nose and throat, the Fitzgerald and Hallpike caloric test [24], testing the otolith reflex of counterrotation of the eyes using a modification of the Fischer and Fluur method [7, 23, 25] and VVD according to tolerance to the cumulative effects of Coriolis and precession accelerations (CCPA) using the method of I. I. Bryanov [2]. During the vestibular tests, we recorded the heart rate (HR) from the ECG, arterial pressure (BP) by the Korotkov method, respiration rate (RR) using a thermistor sensor, severity (score) of vestibulovegetative (VVR) [27] and vestibulosensory (VSR) [32] reactions, CCPA test tolerance time.

In the caloric test, we recorded the electronystagmogram on a Sanei biophysiograph with the eyes open, but the subject wearing lightproof glasses. The time constant of the instrument was 1 s, filter 25 Hz and tape-feeding rate 10 mm/s. In the calibration, a 20° deflection of the eyes corresponded to a 20 mm deflection of the pen on the tape. We determined the quantitative parameters of caloric nystagmus: latency period, duration, frequency and (from tables) velocity of slow phase, amplitude [11]. We calculated the degree of labyrinthine (LP) and directional (DP) prevalence of nystagmus (as percentage, from velocity of slow phase) [30]. We assessed clinically the form of the nystagmic curve [1, 4, 28]. The caloric test was performed 4-6 days before AOH, on the 3d, 15th-17th and 26th-30th days of AOH and on the 2d-4th days of the recovery period; indirect otolithometry was performed 4-6 days before AOH and on the 2d-4th and 8th-10th days of the recovery period; the CCPA tests were done 5-7 days before AOH and on the 2d-4th days of recovery.

Results and Discussion

According to the results of the baseline examination none of the 15 subjects presented any pathology referable to the ear, nose and throat; their hearing was within the normal range for their age. The vestibular history was uneventful, with the exception of one subject who reported poor tolerance of travel. The same subject presented horizontal positional nystagmus when

lying on his left side. We failed to demonstrate reliable changes in quantitative parameters of caloric nystagmus, as compared to those of healthy and young subjects [3]. There was merely a tendency toward decrease in vestibular excitability according to frequency and amplitude parameters and duration of nystagmic reaction. At the same time, 13 subjects presented a change in shape of the nystagmic curve in the form of marked dysmetria, dysrhythmia, "kroketazh," appearance of group movements, rounding of apices and tonicity of nystagmus (Figure 1). VSR (5 to 49 s, scored at 1 to 5) and VVR (scored at 1 to 15) were recorded in 5 subjects. Thus, subject S-v observed marked VVR (up to 15 points) and VSR (sensation of rapid rotation about the longitudinal axis and impaired body schema--5 points) were observed during the hot caloric test. There were no distinct VVR or VSR in young and healthy subjects during caloric testing of the labyrinth by the method of Fitzgerald and Hallpike [3].

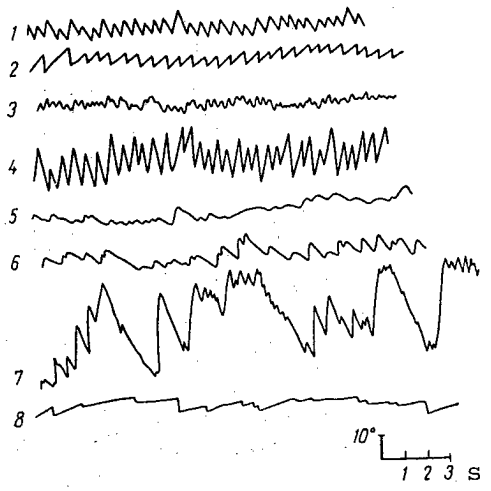


Figure 1.
Variants of forms of culminating phase of caloric nystagmus in tested subjects
1, 2) normal, clonic nystagmus to the left and right, respectively
3) rounded apices, insignificant dysrhythmia
4) hypermetria
5) dysmetria, dysrhythmia
6) dysrhythmia, "kroketazh," nystagmic group volleys
7) dysrhythmia, group nystagmic volleys, dysmetria
8) hypoclonus, dysmetria

Three subjects presented depression of nystagmus associated with marked VVR and VSR. Such dissociation of components of the caloric response can be observed when there is change in activity of central vestibular elements [1, 5, 13].

According to the mean data, LP and DP parameters were in the normal range. At the same time, 8 subjects demonstrated asymmetrical reactions in excess of the physiological scatter of normal values [19, 30 and others], in 3 of whom it was in the form of LP (from 20.8 to 27.1%) and in 6, in the form of DP (from 22.7 to 34%).

Six subjects showed transient increase in ECG changes, which was one of the manifestations of VVR, during the caloric test on the labyrinths (Figure 2).

Baseline otolithometry revealed normoflexia in 6 subjects, change in direction of counterrotation reflex of the eyes (CRE), negative CRE, rotation of eyes in the direction of inclination of the body, and in 3 others, asymmetry that exceeded the physiological scatter (5°).

Evidently, the changes demonstrated in cupular and otolith function in the baseline tests are related to hemodynamic disturbances in both central vestibular structures and on the level of the labyrinth, and they are attributable to the noted deviations of health status. Varying degrees of change in vestibular function are known to occur in cases of marked clinical manifestations of both atherosclerosis and vegetovascular dystonia [5, 12, 13]. Spontaneous vestibular disorders (diverse types of vertigo, static disturbances, etc.) are the most typical. A distinction

of the tested group was presence of signs of vestibular dysfunction (usually only with functional tests); spontaneous vestibular disturbances were found in only 1 out of the 15 subjects.

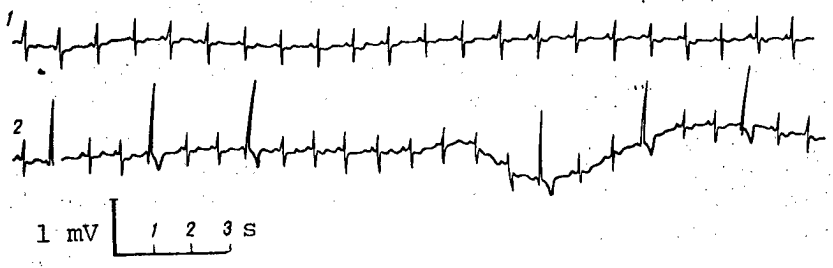


Figure 2. Changes in ECG during caloric tests on labyrinth of subject S. (tape-feeding rate 10 mm/s)
1) baseline, before caloric test. No changes, HR 63.5/min
2) culmination of caloric reaction, 2-3 ventricular extrasystoles per 10-15 normal cardiac cycles, HR 66.7/min

On the 1st-3d day of AOH, a number of subjects presented transient congestion of the nose and ears, tinnitis, occasionally vertigo at rest and when turning to their side, as had also been found previously by other authors [15, 17, 21]. Unlike the findings of other researchers [14, 15], we failed to demonstrate spontaneous and positional nystagmus during AOH. On the 3d day of AOH, we were unable to induce caloric reactions in 3 subjects and on the 27th day, we failed to do so in 1 case. According to the mean data (Table 1), a tendency toward increase in latency period of caloric nystagmus was found on the 3d and 17th days of AOH, there was a tendency toward decline in frequency throughout the AOH period and toward decline of amplitude on the 3d day. In the recovery period, the parameters of caloric nystagmus presented a tendency toward recovery. The changes in shape of the nystagmic curve demonstrated in 13 subjects in the baseline period persisted in the AOH and recovery periods. Sensory and autonomic components of the caloric reaction were enhanced during AOH; in 8 cases, we recorded VSR (in the range of 11 to 93 s, scored at 1 to 5 points) and VVR (1 to 15 points). In subject S-v, caloric testing of the labyrinth on the 3d and 16th days of AOH elicited such intensive subjective (heaving) and objective reactions that irrigation was performed only once. On the 27th day of AOH and in the recovery period, he tolerated all 4 irrigations relatively well. The demonstrated changes could be indicative of some decline of cupular excitability at the early stage of AOH, development of adaptation by the 30th day and restoration of baseline level in the recovery period. The same direction of vestibular responses in young and healthy subjects submitted to hypokinesia had been observed previously [8, 14 and others].

Table 2 lists mean values for dynamics of asymmetry of cupular reactions. As can be seen in Table 2, LP and DP had a tendency toward increase on the 3d day of AOH, according to mean data (DP exceeded the physiological norm), with gradual decline of both parameters by the 30th day and in the recovery period. Individual analysis revealed more distinct changes in function of the

Table 1. Parameters of caloric nystagmus during AOH (M±m)

Time of test	Latency period of nystag.reaction, s				Duration of nystag. reaction, s				Frequency of nystagmus, Hz				Amplitude of nystagmus, degrees				Velocity of slow nystagm.phase, °/s			
	LC	LH	RC	RH	LC	LH	RC	RH	LC	LH	RC	RH	LC	LH	RC	RH	LC	LH	RC	RH
Baseline	36,2±3,86	46,9±5,06	43,8±3,80	41,3±5,08	129±10,9	124±11,5	126±7,1	160±10,8	1,83±0,19	1,80±0,21	1,86±0,15	2,2±0,2	6,16±0,75	4,37±0,70	4,22±0,73	5,7±0,9	14,1±1,78	11,9±2,22	11,5±2,16	15,9±2,79
Day of AOH: 3	43,2±3,64*	51,1±4,69	44,8±3,98	45,8±4,06	143±12,7	120±9,3	127±9,3	140±16,4	1,68±0,16	1,65±0,24	1,62±0,19	1,7*±0,2	3,75*±0,50	4,36±0,88	3,89±0,54	3,9±0,8	11,0±1,55	16,5±4,45	12,9±2,55	12,4±2,60
15-17	41,1±4,30	52,1±5,71	47,0±3,05	45,5±4,07	133±2,6	127±9,4	125±8,3	138±13,0	1,55±0,18	1,65±0,17	1,3**±0,15	1,5**±0,2	4,24*±0,56	4,33±0,65	4,46±0,65	5,2±0,9	12,3±2,10	13,0±2,61	11,5±2,19	16,7±4,12
27-30	46,2±3,43*	46,5±3,27	43,6±1,63	42,7±5,08	127±13,3	130±13,5	130±9,3	150±13,5	1,68±0,18	1,74±0,24	1,56±0,15	1,9±0,2	3,97*±0,65*	5,13±1,01	4,02±0,63	6,6±1,8	13,3±2,89	18,2±4,14	12,2±2,06	23,2±7,19
Recovery period (2d-4th days)	44,0±4,36	32,7±5,28	37,6±3,77	36,1±4,52	117±9,3	125±8,4	124±5,4	144±12,9	1,68±0,22	2,21±0,34	1,79±0,32	2,2±0,4	4,11±0,67	4,89±0,87	5,99±1,11	4,5±0,6	11,7±1,21	20,0±5,14	15,1±2,44	19,3±5,36

Key: LC, LH) irrigation of left ear with water at 30 and 44°C, respectively
RC, RH) irrigation of right ear with water at 30 and 44°C, respectively

*P<0.05 **P<0.01

vestibular analyzer as a paired organ during AOH and in the recovery period. Thus, DP or LP exceeding the physiological norm (21.7 to 38.7%) appeared in 5 out of 7 subjects who presented functional equilibrium in the baseline period. The asymmetry demonstrated in the background period in 5 subjects (from 20.8 to 34%) increased at different stages of AOH (from 22.2 to 49.4%) and remained virtually constant in 1 subject throughout the period of the study. One subject presented change in direction of asymmetry and in another the asymmetry disappeared. The results of these studies revealed that subjects who presented vestibular asymmetry during AOH demonstrated more marked autonomic components in the caloric reaction and greater changes in parameters of caloric nystagmus than those with symmetrical reactions. Such distinctions of vestibular reactions in young and health subjects submitted to hypokinesia had also been noted previously [14].

Thus, our findings confirmed the opinion of some authors [9, 20, 22, 30] that LP and DP levels exceeding the physiological norm not only indicate that there is asymmetrical activity of the right and left labyrinths, but reflect to some extent vestibular dysfunction, which is sometimes discrete.

Testing of otolith function revealed that CRE changed in all subjects on the 2d-4th days of AOH. Thus, an increase in asymmetry (to 5.8 and 9.0°) was demonstrated in 2 subjects, appearance or increase of negative CRE (to 12.2°) was found in 8, a tendency toward hyporeflexia in 4 (5-5.5°), which was combined in 2 cases with negative CRE. On the 8th-10th day of the recovery period, the otolith reflex was demonstrated in 3 subjects, asymmetry increased in 3, and in 5 cases the parameters held at the 2-4-day level, i.e., by the 8th-10th day after 30-day AOH

there was normalization of the otolith reflex in 25% of the older subjects who presented deviations in health status. This direction of changes in CRE had been found in cosmonauts following long-term missions [7].

Table 2. Dynamics of levels of vestibular asymmetry

Stage	Baseline	Days of AOH			Recovery period (2d-4th days)
		3	15—17	27—30	
LP	11,34±2,12	12,33±2,81	9,07±2,11	10,05±3,10	11,17±2,01
DP	17,00±2,96	20,82±3,78	17,87±3,46	14,32±2,97	14,77±3,14

Note: LP and DP were calculated from the velocity of the slow phase of caloric nystagmus, %. Norm--up to 20%.

Determination of VVS level after AOH failed to demonstrate changes in mean duration of tolerance to CCPA test in the tested subjects. There was even some tendency toward its increase. Thus, in the baseline period tolerance to the test constituted 6.57±1.04 min (VVR 8.33±1.84 points), whereas after AOH it constituted 7.16±0.98 min (VVR 7.40±1.97). The direction of changes in VVR before and after AOH was the same, and it was characterized by unreliable increase of pulse rate, increase in RR and a tendency toward elevation of BP. If we consider the means for BP, RR and HR obtained before the CCPA test to be 100%, minimal BP immediately after the test would be 104.5% before AOH and 113.6% after AOH, pulse pressure would be 91.8 and 93.9%, respectively. Maximum BP, RR and HR changed by 1-4%. In subject S-v, before performing the CCPA test the ECG showed ventricular extrasystoles, the number of which increased during the test; extrasystoles were also demonstrated 10 min after termination of the test. No changes on the ECG were demonstrable when the CCPA test was repeated 10 days later. Consequently, the post-AOH CCPA test elicited more marked vestibulovascular reactions with appearance of ventricular extrasystoles, which confirms data in the literature [16] concerning the relevance of vestibulometric tests to detection of latent cardiovascular pathology, and it stresses the desirability of taking the ECG during such tests on older subjects.

Thus, analysis of the results of our studies revealed that, in older subjects with signs of atherosclerosis and VVD of the hypertensive type, vestibular stimulation demonstrates some symptoms of change in vestibular function both on the level of the labyrinths (cupular and otolith systems) and central vestibular elements. It must also be noted that such vestibular functional disturbances were not found in healthy subjects of a similar age, according to data in [18]. At the same time, in the case of 30-day AOH (-8°), the direction of vestibular responses corresponded in essence to reactions of young and healthy subjects. AOH elicited changes in otolith function differing in degree in all subejcts, according to the results of recording CRE and resembled the change in this parameter in cosmonauts in the postflight period. No reliable changes in cupular reflexes (with the exception of development of asymmetry) were demonstrable under the effect of AOH. There was no worsening of tolerance to motion sickness (CCPA test) after AOH. Recording of ECG

during vestibular tests enabled us to demonstrate vestibulovascular reactions in this category of subjects.

Data obtained under model conditions revealed that, in older subjects with deviations of health status, the functional capacities of the vestibular system under the effect of 30-day AOH were virtually the same as those of healthy and young people.

BIBLIOGRAPHY

1. Blagoveshchenskaya, N. S., "Otonevrologicheskiye simptomy i sindromy" [Otoneurological Symptoms and Syndromes], Moscow, 1981.

2. Bryanov, I. I., VOYEN.-MED. ZHURN., 1963, No 11, pp 54-56.

3. Bodo, D., Baranova, V. P., Matsnev, E. I. et al., KOSMICHESKAYA BIOL., 1973, No 4, pp 47-51.

4. Bulayev, Yu. O., "Vestibulometric Characteristics of Nonsuppurative Lesions in the Labyrinth in the Light of Differential Diagnosis of Retrolabyrinthine Diseases," author abstract of candidatorial dissertation in medical sciences, Moscow, 1983.

5. Grigoryev, G. M., "Vestibular Symptoms Associated With Some Forms of Vascular Pathology," author abstract of doctoral dissertation in medical sciences, Chelyabinsk, 1976.

6. Kakurin, L. I., in "Simpozium po kosmicheskoy biologii i meditsine. 10-y. Tezisy" [Summaries of Papers Delivered at 10th Symposium on Space Biology and Medicine], Moscow, 1977, pp 30-32.

7. Kornilova, L. N., Syrykh, G. D., Tarasov, I. K. et al., VESTN. OTORINOLAR., 1979, No 6, pp 21-24.

8. Lapayev, E. V. and Platonov, I. B., ZHURN. USHN. NOS. I GORL. BOL., 1973, No 5, pp 16-19.

9. Levashov, M. M., in "Syezd otorinolaringologov SSSR. 8-y. Tezisy dokladov" [Summaries of Papers Delivered at 8th Congress of USSR Otorhinolaryngologists], B, Moscow, 1982, pp 202-203.

10. Luchikhin, L. A. and Patrin, A. F., VESTN. OTORINOLAR., 1983, No 4, pp 32-38.

11. Markaryan, S. S. and Sidelnikov, I. A., ZHURN. USHN. NOS. I GORL. BOL., 1971, No 6, pp 90-106.

12. Petrova, Ye. I., "Vestibulovascular reactions in Diagnosis of Labyrinthine Diseases," author abstract of doctoral dissertation in medical sciences, Moscow, 1982.

13. Pomukhina, A. N., "Signs and Causes of Vestibular Dysfunction With Meniere's Disease," author abstract of doctoral dissertation in medical sciences, Moscow, 1982.

14. Khilov, K. L., Kurashvili, A. Ye. and Rudenko, V. P., in "Problemy kosmicheskoy biologii" [Problems of Space Biology], Moscow, 1969, Vol 13, pp 182-188.

15. Khondkarian, O. A., Kalinovskaya, I. Ya., Shaposhnikov, Ye. A. et al., in "Vserossiyskiy syezd nevropatologov i psikhiatrov. 3-y. Tezisy dokladov" [Summaries of Papers Delivered at 3d All-Russian Congress of Neurologists and Psychiatrists], Moscow, 1974, Vol 1, pp 453-457.

16. Yakovleva, I. Ya., Baranova, V. P., Kornilova, L. N. et al., KOSMICHESKAYA BIOL., 1972, No 4, pp 49-54.

17. Yakovleva, I. Ya., Baranova, V. P., Matsnev, E. I. et al., VESTN. OTORINOLAR., 1974, No 1, pp 25-28.

18. Aust, G., in "Aerospace Medicine. Annual Scientific Meeting," New Orleans, 1978, pp 140-141.

19. Baloh, R. W. and Honrubia, V., "Clinical Neurophysiology of the Vestibular System," Philadelphia, 1979.

20. Boniver, R., J. FRANC. OTO-RHINO-LARYNG., 1977, Vol 26, pp 685-692.

21. Burgeat, M., Toupet, M., Loth, D. et al., ACTA ASTRONAUT., 1981, Vol 8, pp 1019-1027.

22. Coats, A. C., ANN. OTOL. (St. Louis), 1966, Vol 75, pp 1135-1159.

23. Fischer, M. H., ALBRECHT V. GRAEFES ARCH. OPHTHAL., 1930, Vol 123, pp 509-531.

24. Fitzgerald, G. and Hallpike, C. S., BRAIN, 1942, Vol 65, pp 115-137.

25. Fluur, E., ACTA OTO-LARYNG. (Stockholm), 1975, Vol 79, pp 111-114.

26. Gramowski, K.-H. and Unger, E.-Z., LARYNG. RHINOL., 1973, Vol 52, pp 541-547.

27. Graybiel, A., Wood, C. D., Miller, E. F. et al., AEROSPACE MED., 1968, Vol 39, pp 543-545.

28. Jongkees, L. B. W. and Philipszoon, A., ACTA OTO-LARYNG. (Stockholm), 1964, Suppl 189.

29. Jongkees, L. B. W., ARCH. OTOLARYNG., 1973, Vol 97, pp 77-81.

30. Jongkees, L. B. W. and Gasthnis, W., J. FRANC. OTO-RHINO-LARYNG., 1973, Vol 22, pp 97-101.

31. Van der Laan, F. L. and Oosterveld, W. I., AEROSPACE MED., 1974, Vol 45, pp 540-547.

32. Lackner, I. R. and Teixeira, B. A., AVIAT. SPACE ENVIRONM. MED., 1977, Vol 48, pp 248-253.

UDC: 613.693-07:612.014.477-063

CHARACTERISTICS OF ACCELERATIONS IN AEROBATIC FLIGHT AS A SPORT

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 12 Sep 84) pp 20-22

[Article by V. G. Voloshin, Yu. I. Bykova, A. V. Opryshko and N. A. Lapshina]

[English abstract from source] Thirty well-qualified flying sportsmen, aged 22-42, who performed 210 aerobatic flights, onboard a sporting airplane Yak-50, were examined, using an automatic monitoring system. The flyers were exposed to +9 Gz and -6 Gz as a maximum the duration of which was 10 s and 5 s, respectively. The onset rate varied from 0.5 to 2.5 G/s (with the mean rate 1 G/s), reaching 4.2 G/s as a maximum. On the average, the training flight lasts 25 min, 45-50% of which the pilot experiences acceleration of various values and different sign. The most common acceleration values are: +6 and +7 Gz or -4 and -5 Gz.

[Text] Refinement of sports airplanes has made it possible in recent years to complicate significantly the sets of aerobatic maneuvers in order to achieve the highest results. Performance of more complicated maneuvers in limited space led to an increase in aerobatic accelerations. Since there is alternation of straight and inverted maneuvers in flight, these accelerations differ in sign. Soviet and foreign authors believe that their effects on sports pilots can elicit serious impairment of performance [1-6].

In order to assess the safety of maneuvers involving rapid alternation of positive and negative accelerations, it is necessary first of all to know their parameters. However, there is virtually no information in the literature on this score.

Our objective here was to investigate the dynamic characteristics of accelerations in aerobatic sports flights.

Methods

The studies were pursued with the participation of 30 sports pilots qualified as masters and master candidates of sports who are members of the USSR combined team of aerobatics ranging in age from 22 to 42 years.

The parameters of aerobatic accelerations were studied on the basis of flight logs (210 flights) using the SARPP-12N (system for automatic recording of flight parameters), which was installed in the cabbin of a YaK-50 sports airplane. The ±Gz was recorded using a calibrated sensor of accelerations installed at the level of the hips of a pilot seated in the aircraft cockpit. Physiologicallly significant minimal accelerations were taken as 1.5 G for +Gz and 0.5 G for -Gz. Accelerations were divided into several levels for analysis: 1.5-2 G, 2-3 ... 8-10 G for +Gz and 0.5-1, 1-2 ... 4-5 G for -Gz (Figure 1).

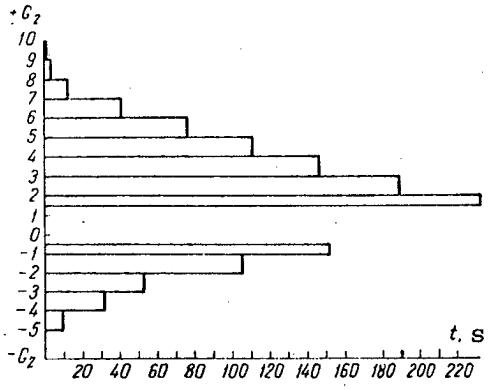


Figure 1.
Duration of exposure to aerobatic accelerations

In addition to Gz, we determined the duration of exposure to accelerations of each level and, as an integral characteristic, we calculated parameter $G \cdot t$ for each level (acceleration multiplied by its duration). We counted all ±Gz per flight. On the basis of these data, we plotted histograms of distribution of $G \cdot t$ and number of accelerations on each level.

Results and Discussion

Practice flights lasted an average of 25 min from take-off to landing. Aerobatics (performance of a set of maneuvers) lasted a mean of 20 min.

Depending on the pilot's skill and specific flight assignments, it may consist of straight or inverted maneuvers. The most difficult flights were those with alternation of straight and inverted aerobatic maneuvers, and then the pilot was exposed to rapidly increasing accelerations with different signs.

Maximum accelerations recorded on the YaK-50 accelerometer constituted +9 and -6 G. The total number of accelerations (over ±2 G) fluctuated from 120 to 200 per flight, depending on the flight assignment. As an example, we analyzed the profile of aerobatic accelerations during performance of a typical practice flight by D-na, an international class master of the sport (see Figure 2). With a total flight duration of 27 min, aerobatics lasted 20.3 min. The pilot was exposed to positive accelerations (over +1.5 G) for 323 s, or 26.5% of the time, and to negative accelerations (over -0.5 G) for 207 s, or 17% of the time. Consequently, the pilot was exposed to accelerations with different signs for 43.5% of the time. In other pilots, this time constituted 45 to 50%.

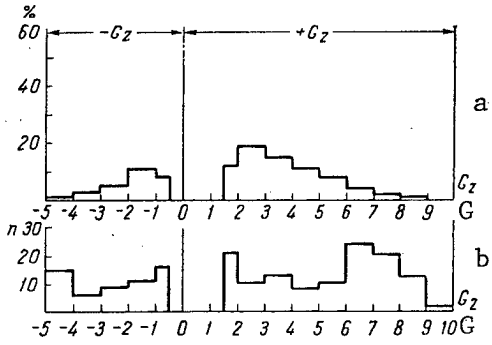


Figure 2.
Histograms of distribution of $G \cdot t$ (%) (a) and of number of accelerations (b) of different levels

Maximum duration of exposure to different positive accelerations constituted 10 s and to negative ones, 5 s.

The rate of build-up of accelerations ranged in most cases from 0.5 to 2.5 G/s, depending on the stunt performed (mean 1 G/s), the maximum being 4.2 G/s.

Analysis of duration of exposure to each level of accelerations revealed that the pilot was exposed for most of the flying time (230 s) to +Gz of 1.5 to 2 G. As can be seen in the histogram (see Figure 1), exposure to higher levels decreased uniformly with both +Gz and -Gz. Analogous results were obtained from analysis of histograms of parameter $G \cdot t$ (see Figure 2a).

On the basis of the obtained data, one could have assumed that this was not a difficult flight according to overall duration of accelerations in excess of +6 and -5 G. However, the histogram of distribution of number of accelerations (see Figure 2b) indicates that their maximum number was on the level of +6 - +8 G and -4 - -5 G.

The Figure shows that, with a total of 170 accelerations, 44 were on the level of +6 - + 8 G and 15 at -4 - -5 G. Brief exposure to such accelerations is hazardous because the body does not have time for adequate adjustment to their rapid alternation for optimum function. This indicates that it is desirable to pursue in-depth investigation of effects on the body of accelerations with this profile, not only with reference to flight safety, but health of sports pilots as a whole. Investigation of compensatory reactions of the cardiovascular system is of special interest.

BIBLIOGRAPHY

1. Babushkin, V. I., AVIATSIYA I KOSMONAVTIKA, 1972, No 2, p 40.

2. Babushkin, V. I. and Romanov, N. V., VOYEN.-MED. ZHURN., 1968, No 11, pp 87-89.

3. Vasilyev, P. V. and Kotovskaya, A. R., in "Patologicheskaya fiziologiya ekstremalnykh sostoyaniy" [Pathological Physiology of Extreme States], Moscow, 1973, pp 290-311.

4. Idem, in "Osnovy kosmicheskoy biologii i meditsiny" [Bases of Space Biology and Medicine], Moscow, 1975, Vol 2, Bk 1, pp 177-231.

5. Isakov, P. K., VOYEN.-MED. ZHURN., 1972, No 3, pp 63-66.

6. Sharp, G. R., "Aviation Medicine Physiology and Human Factors. Pt 2: Biodynamics," London, 1978, pp 208-224.

UDC: 629.78:612.014.477-063

DISTINCTIONS IN REACTIONS TO ACTIVE ORTHOSTATIC AND WATER-LOADING TESTS OF SUBJECTS DIFFERING IN TOLERANCE TO +Gz ACCELERATIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 8 Jan 85) pp 22-27

[Article by I. G. Dlusskaya and M. N. Khomenko]

[English abstract from source] Thirty-seven healthy male test subjects, aged 19-21, with different +Gz acceleration tolerance were examined. Their blood pressure (BP) and heart rate (HR) during 5-min tilt tests and 2% water loading tests were measures 2-3 weeks prior to centrifugation. Quantitative evaluation of orthostatic tolerance using an orthostatic index and BP and HR responses to tilt tests before and after water loading revealed specific features of cardiovascular regulation in the subjects with high and low +Gz acceleration tolerance. The negative predictive indicators include: decreased BP, HR and cardiac index in the supine position in combination with high orthostatic tolerance, as well as decreased orthostatic tolerance in combination with a lower function of vasoconstrictor mechanisms in the upright position and a lower sensitivity of carotid sinus reflexes to blood volume changes during tilt and water loading tests. When examining test subjects with high +Gz tolerance, preference should be given to those who can well tolerate tilt tests and show moderately high BP and HR in the supine position, as well as to those who exhibit a noticeable increment of diastolic BP during 5-min tilt tests.

[Text] Efforts have been made repeatedly to elaborate indirect methods of predicting tolerance to +Gz accelerations [4-7, 11, 18], and the method involving use of static physical loads may be mentioned as the most informative one [5]. Along with tested complicated loading tests, which can be performed in departments of expert medical evaluation of flight personnel (VLE) and hospitals, it is interesting to develop simple informative methods that could be used by unit ["chast"] physicians. A pilot's tolerance to +Gz accelerations depends largely on activity of compensatory mechanisms that are triggered when there is sudden redistribution of circulating blood volume (CBV). Maintenance of the required blood pressure (BP) level is determined by the extent of developing tachycardia caused by a signal from baroreceptors of the sinocarotid region [12-17]. A functional test, in which there is deposition of 300-400 mℓ blood in the lower extremities and compensatory tachycardia with increase in

total peripheral resistance, is an orthostatic test, but it has not gained a high practical rating in medicine for prognostic purposes [11, 18]. However, individual evaluations of changes in systolic (BP_s) and diastolic (BP_d) pressure, heart rate (HR) in the first minutes after changing to erect position may be of special interest [1, 15]. The combination of an orthostatic test and 2% water-loading test, in which brief increase in CBV (by 300-400 mℓ), some increase in HR and elevation of BP_d occur, may turn out to be an important factor [2]. On the basis of classification of subjects according to their tolerance to +Gz, we analyzed the differences in their BP and HR at rest and distinctions in regulation of physiological functions during a set of functional tests--5-min active orthostatic tests (AOT) before and after a 2% water load (WL).

Methods

We tested 37 specially selected healthy men 19-21 years of age who differed in tolerance to accelerations. In order to determine their tolerance to head-pelvis (+Gz) accelerations, the subjects underwent an expert test involving rotation on a centrifuge, which is used in VLE practice: accelerations of 3 and 5 G, each for 30 s, at a build-up rate of 0.4 G/s [11]. We performed an active orthostatic and water-loading test 2-3 weeks before the test with accelerations. After rising in the morning and attending to hygienic procedures, the subject returned to bed and maintained a horizontal position. After 20-25 min, we measured his HR (for 15 s) and BP by the Korotkov method 3 times. The subject then arose slowly and the same readings were taken every minute for 5 min in erect position. After the orthostatic test, in seated position the subject drank water (boiled, at room temperature) in an amount equaling 2% of his total weight within 4-5 min and again assumed a horizontal position. Measurement of HR and BP in horizontal position and during 5-min AOT was repeated 30 min after water intake. The subject emptied his bladder (volume of urine was measured) and returned to bed. The volume of urine eliminated in the first hour after the WL, expressed as percentage of consumed water, was used to assess fluid retention. As shown previously, fasting examination with AOT in the morning is more informative with regard to demonstration of individual functional differences in the cardiovascular system than testing in the daytime [3]. To characterize cardiac function at rest, we calculated the cardiac function index (CFI), which is usually recommended to evaluate the heart's reactions to a physical load [8]:

$$CFI = \frac{HR\ (\text{per min}) \cdot BP_s\ (\text{mm Hg})}{100}$$

Orthostatic tolerance was assessed using the formula for the orthostatic index (OI):

$$OI = \frac{BP_s\ (\text{supine})}{BP_s\ (\text{erect})} \cdot \frac{BP_d\ (\text{erect})}{BP_d\ (\text{supine})} \times \frac{HR\ (\text{erect})}{HR\ (\text{supine})} \sqrt{S^2BP_s + S^2BP_d + S^2HR}$$

where S is standard mean deviation for parameters in orthostatic position. In healthy subjects, OI constitutes a mean of 10 units, and an increase in OI is indicative of worsening of orthostatic tolerance [2, 3].

In addition to OI and CFI, we analyzed differences between BP and HR in the different groups at rest (supine before orthostatic test) and changes (Δ, %) in BP_s and BP_d in orthostatic position, as compared to baseline values supine. Statistical reliability of differences was established using Student's criterion.

Results and Discussion

A total of 26 men tolerated well the test with rotation on the centrifuge and 11 showed diminished tolerance to accelerations. AOT (5 min) was subjectively tolerated well by all of the men, but the objective evaluation of orthostatic tolerance according to OI differed. Individual values for OI were in the range of 7.1-20.1 U, the mean for the entire group being 11.9 U. Figure 1 illustrates the histogram of these OI values with consideration of tolerance to accelerations. The two peaks on the histogram enabled us to divide the subjects into four groups. The first 2 consisted of individuals with optimum values of OI, from 7 to 12 U, but different tolerance to accelerations: good--18 subjects (1st group) and low--5 men (2d group). In the remaining 14 subjects, evaluation of AOT tolerance was low (OI 15-20 U). Tolerance to accelerations was good in 8 of these subjects (3d group) and low in 6 (4th group).

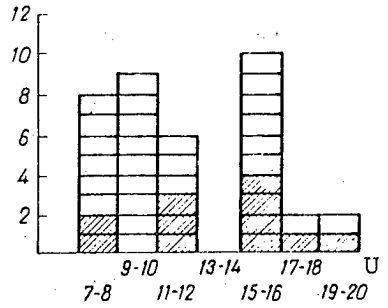


Figure 1.
Histogram of OI values of subjects X-axis, OI (units--U); y-axis, number of subjects. Cross-hatched sections refer to men with diminished tolerance to accelerations

These data confirm once more that diminished or good tolerance to AOT cannot per se serve as grounds to predict tolerance to +Gz accelerations. Additional analysis was made of data obtained from the AOT in order to detect other distinctions in subjects differing in tolerance to accelerations. It had already been noted previously that pilots with relatively low BP had low tolerance to aerobatic maneuvering accelerations [7]. In this study, we analyzed CFI at rest supine for this purpose, since this parameter takes into consideration low base values of not only BP, but HR. Investigation of severity of changes in HR and BP during AOT was another stage of our analysis, in order to define normotonic and sympathotonic types of reactions, as well as the share of involvement of central and peripheral levels of control of cardiovascular functions in terms adopted in cardiological practice [9, 10]. These data for the above-described groups of subjects are listed in Table 1 and illustrated in Figure 2.

The first 2 groups of subjects with optimum OI (up to 12 U) can be defined as moderate sympathotonics with prevalence of reactions in the central regulatory element, since their HR and BP_d increased reliably (by 30 and 14%, respectively) in the 5th min of AOT, with negligible decline of BP_s. However, the 2d group of subjects presented lower BP_s (less than 110 mm Hg), HR (less that 50/min) and CFI (less than 60 U). In spite of these differences, the 2d group of subjects managed well to maintain BP on a satisfactory level under "mild" AOT conditions, but under the "rigid" conditions of exposure to accelerations their compensatory mechanisms were inadequate.

Table 1. CFI at rest (U), OI (U), HR (per min) and BP (mm Hg) during morning 5-min AOT in subjects with different tolerance to +Gz accelerations

Group	Toler. to +Gz acceler.	OI	Before AOT, supine				5th min AOT, erect		
			HR	BP_s	BP_d	CFI	HR	BP_s	BP_d
1	GOOD	9,3±0,33	58±1,2	112±1,5	73±1,3	65±1,5	75±2,2*	109±1,3	83±2,3*
2	LOW	10,2±1,7	48±1,5**	105±3,2	72±2,2	51±2,4**	63±3,4*	102±3,0	83±1,8*
3	GOOD	16,0±1,5	59±1,0	114±2,0	73±1,5	68±3,3	86±1,6*	109±1,7	88±1,3*
4	LOW	16,2±0,9	52±2,1**	111±2,0	72±2,8	57±1,7	77±5,4*	100±3,4*	79±1,8

*P<0.05, as compared to supine parameters.
**P<0.05 in 2d and 4th groups, as compared to 1st and 3d groups.

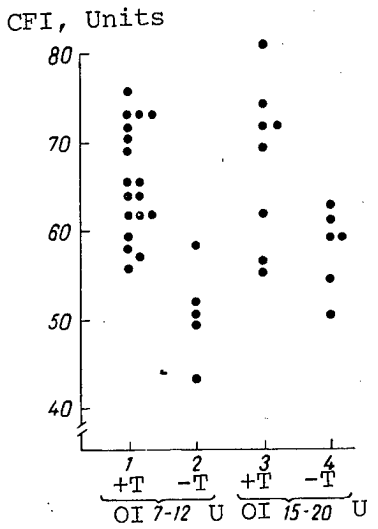


Figure 2.
Distribution of CFI values at rest in subjects with different tolerance to AOT (assessed by OI) and to accelerations
Here and in Figure 3:
X-axis, group of subjects (1-4) and rating of their tolerance (+T good, -T poor)

In the 3d and 4th groups of subjects, the lower rating of tolerance to AOT and OI (OI over 15 U in all cases) was related primarily to greater increase in HR (by 46-48%) during 5 min in orthostatic position. Considering the BP readings, the subjects in the 3d group can be referred to as distinct sympathotonics with strong reactions on the peripheral vasoconstrictive level: by the 5th min of AOT their BP_d rose by 20% with insignificant drop of BP_s. In the 4th group of subjects, the vasoconstrictive reaction was much milder: BP_d rose only by 11% (P>0.05), while BP_s dropped by 10% (P<0.05).

Figure 3 shows that individual values for BP_d increment in the 5th min in orthostatic position were essentially above 12 mm Hg in the 3d group and below this level in the 4th group. Of these two groups, the sympathotonic 3d group with stronger (more active) mechanisms of peripheral vasoconstriction was more tolerant to accelerations.

Analysis of the causes of diminished tolerance to accelerations in the 2d and 4th group of subjects with low base HR at rest made it interesting to refer to the hypothesis of Lindblad et al. [19], to the effect that changes in HR and tonus of peripheral vasoconstrictors are always controlled according to a specific program in each individual. For example, during the orthostatic test, the increment in HR is inversely proportional to resting HR in supine position and proportional to base level of sympathetic stimulation of muscle fibers (SSMF) providing for peripheral vasoconstriction. As it was established, the higher the base SSMF in an individual, the lower its lability and the less

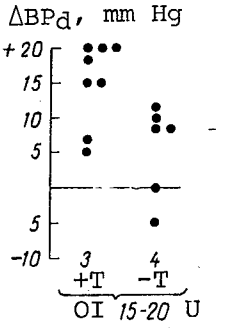


Figure 3.
Distribution of values for BP_d increment in 5th min of AOT in subjects of 3d and 4th groups

it increases in the orthostatic test, while the burden of functional change is referable to increased HR [13, 19]. Hence, in subjects of the 2d and, particularly, 4th groups, low tolerance to accelerations could be attributed to a significant extent to inadequate lability of mechanisms of vasoconstrictive regulation in the case of abrupt redistribution of CBV.

Table 2 lists the main results obtained with the 2% water-loading tests. Rather high values for elimination of ingested water (50% or more within 1 h after WL) can be related to the fact that, under these conditions, the subjects were in horizontal position for almost all of the time, and this was instrumental in intensifying the reaction to WL. A tendency toward greater fluid retention was demonstrated in the 2d and 4th groups of subjects who had relatively inadequate vasoconstrictive mechanisms.

Table 2. OI (U), HR (per min), BP (mm Hg) and diuresis (% of WL) after 2% water-loading test in subjects with different baseline orthostatic stability (according to OI) and tolerance to +Gz accelerations (M±m)

Group	Toler. to acceler.	OI			HR	BP_s	BP_d	HR	BP_s	BP_d	Diuresis, % WL (in 1 h after WL)
		before WL	after WL 30 min	after WL 60 min	supine, 60 min after WL			erect, 5-min AOT, 60 min after WL			
1	GOOD	9,3±0,3	8,0±0,6	9,5±0,7	55±1,4	114±1,1	79±1,5	71±2,5	113±1,4	87±1,5	62±3,6
2	LOW	10,2±1,7	8,3±0,7	10,7±1,1	45±2,2**	108±2,9	79±2,1	59±1,2	101±2,7	86±2,4	53±5,5
3	GOOD	26,0±1,5	9,4±0,9*	10,3±0,7*	56±0,9	116±2,3	75±3,7	76±3,1	112±3,4	88±2,9	58±4,3
4	LOW	16,2±0,9	10,4±1,0*	10,3±1,5*	49±2,3**	112±2,8	73±2,3	70±6,3	109±3,3	85±2,2	48±7,3

*P<0.05, as compared to parameters before WL.
**P<0.05, for differences between 1st and 2d, 3d and 4th groups.

Improvement of orthostatic stability after WL was more marked and lasted longer in the 3d and 4th groups (see Table 2): OI was diminished by 40% for 1 h after WL (P<0.05). This improvement of orthostatic stability in subjects with markedly sympathotonic type of reaction to AOT was characterized by a lesser increment of HR in orthostatic position and better stabilization of BP. Interestingly, the most marked decline of tachycardia in orthostatic position after WL (from 46% in baseline period to 36%) was demonstrated in the 3d group of subjects, it was somewhat less marked in the 4th group (48 and 43%, respectively). The effects of WL on orthostatic reflexes can apparently be related to brief increase in CBV and in venous return to the heart [2]. Perhaps, the increase in CBV has an effect on the system of sinocarotic baroreceptors that is analogous to the one of β-blocking agents and, consequently, it diminishes the HR increment in orthostatic position [14, 16, 20]. On this basis, it can be assumed that, in the 3d group of subjects, the reflexes of

the sinocarotid zone are more sensitive to changes in CBV (increase after WL and decrease with accelerations) than the 4th group, and the difference in their tolerance to accelerations could be related to this.

In summary, it can be stressed that endurance of active orthostatic test with use of OI, unlike the usually qualitative criteria, enables us to provide a quantitative evaluation over a wide range. However, in itself an evaluation of orthostatic stability cannot be used to predict tolerance to +Gz accelerations in view of the "mildness" of this functional test. Additional analysis of dynamics of orthostatic stability after loading the vascular system with a volume of liquid and evaluation of changes in HR and BP in the first minutes in orthostatic position enabled us to demonstrate combinations of informative criteria of the functional state of the cardiovascular system in individuals differing in tolerance to accelerations. Thus, for subjects with low tolerance to +Gz accelerations, the following are typical criteria:

> Relatively low HR (<50/min, BP_s<110 mm Hg) and CFI (<60 U) at rest in the morning in supine position, with good rating of orthostatic stability (OI <12 U).
>
> Relative weakness of vasoconstrictive mechanisms in orthostatic position (BP_d<12 mm Hg) and diminished sensitivity of the system of sinocarotid reflexes to changes in blood volume (mild depression of tachycardia in orthostatic position after WL) with poorer orthostatic stability (OI >15 U).

When screening individuals with good tolerance to +Gz accelerations, one should apparently give preference to those with good tolerance to 5-min AOT and moderately high BP and HR at rest in supine position, as well as those of the sympathotonic type, in whom the BP_d increment during 5-min AOT is well-marked (over 12 mm Hg).

BIBLIOGRAPHY

1. Avetikyan, Sh. T., FIZIOL. CHELOVEKA, 1983, Vol 9, No 2, pp 242-249.

2. Balakhovskiy, I. S. and Dlusskaya, I. G., Ibid, 1981, Vol 7, No 1, pp 130-137.

3. Vlasov, V. D., Dlusskaya, I. G. and Nekhayev, A. S., VOYEN.-MED. ZHURN., 1982, No 2, pp 56-58.

4. Voloshin, V. G., Suvorov, P. M., Kotovskaya, A. R. et al., Ibid, 1974, No 5, pp 56-59.

5. Glod, G. D., Suvorov, P. M., Asyamolov, B. F. et al., in "Gagarinskiye chteniya po aviatsii i kosmonavtike. 13-ye. Sektsiya 'Problemy aviatsionnoy i kosmicheskoy meditsiny i biologii.' Tezisy dokladov" [Summaries of Papers Delivered at 13th Gagarin Lecture Series on Aviation and Astronautics. Section of "Problems of Aviation and Space Medicine"], Moscow, 1983, p 76.

6. Glod, G. D., Khomenko, M. N., Plakhotnyuk, L. S. et al., in "Prognozirovaniye v prikladnoy fiziologii" [Forecasting in Applied Physiology], Frunze, 1984, Vol 1, pp 491-492.

7. Kolesnikov, S. V., Vartbaronov, R. A., Kotovskaya, A. R., KOSMICHESKAYA BIOL., 1976, No 4, pp 30-34.

8. Moskalenko, N. P. and Glezer, M. G., KARDIOLOGIYA, 1979, No 11, pp 112-116.

9. Osadchiy, L. I., "Polozheniye tela i regulyatsiya krovoobrashcheniya" [Position of the Body and Control of Circulation], Leningrad, 1982, p 42.

10. Suvorov, P. M., "Physiological Studies With Centrifuge in the Practice of Expert Medical Certification of Flight Personnel and Screening System," author abstract of doctoral dissertation, Moscow, 1969.

11. Lyusov, V. A., Matusov, A. P., Pomerantsev, V. P. et al., "Fizicheskiye trenirovki pri ishemicheskoy bolezni serdtsa. Metod. rekomendatsii" [Physical Conditioning in the Presence of Ischemic Heart Disease. Methodological Recommendations], Moscow, 1979, p 11.

12. "Aviation Medicine," London, 1978, Vol 1, pp 220-222.

13. Bath, E., Lindblad, L. and Wallin, B., J. PHYSIOL. (London), 1981, Vol 311, pp 551-564.

14. Bevegard, S., Castenfors, J. and Lindblad, L., ACTA PHYSIOL. SCAND., 1977, Vol 99, pp 300-312.

15. Debru, J., Morin, B. and Mikler, F., ARCH. MAL. COEUR, 1979, Vol 72, special issue, pp 114-119.

16. Eckberg, D., CIRCULAT. RES., 1980, Vol 47, pp 208-216.

17. Greenleaf, J., Stinnett, H., Davis, G. et al., J. APPL. PHYSIOL., 1977, Vol 42, pp 67-73.

18. Klein, K., Bruner, H., Lovy, D. et al., AEROSPACE MED., 1969, Vol 40, pp 293-297.

19. Lindblad, L., Afterhog, J. and Wallin, B., ACTA PHYSIOL. SCAND., 1981, Vol 111, pp 509-510.

20. Vatner, S., Boettcher, D., Heydricks, G. et al., CIRCULAT. RES., 1975, Vol 37, pp 236-242.

UDC: 612.766.2-08:612.763

EFFECT OF IMMERSION HYPOKINESIA ON CHARACTERISTICS OF PROGRAMMED VOLUNTARY MOVEMENTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 19 Jul 84) pp 27-32

[Article by A. V. Kirenskaya, I. B. Kozlovskaya and M. G. Sirota]

[English abstract from source] The effect of immersion hypokinesia on the precision of programme-type voluntary movements was investigated using standard test movements and quantitative analytical methods. The exposure did not cause disorders in the programme mechanisms but reduced significantly the precision range of the motor control system. The loss of precision was at its maximum (by 100% and over) on immersion day 3. The universality and consistency of the above changes indicated their close association with the specific exposure while the fast rate of their development suggested their reflex nature.

[Text] Coordination disturbances are among the regular consequences of spaceflights. Kinematic changes in locomotor acts and decline of vertical stability are constantly recorded after exposure to weightless and conditions that simulate it [3, 4, 8, 13, 16, 17]. Experiments conducted during flights over a Keplerian parabola, in weightlessness, revealed difficulties in performing precision motor problems, diminished accuracy of reproducing graded and differentiated muscular exertions similar in magnitude and increase in motor reaction time [9, 10, 12, 13]. Analogous difficulties in gaging muscular exertions and incommensurate movements were noted on the 1st day of flight by crews of space missions [6]. The mechanisms of these changes, which are logically apparent, have not yet been investigated. It is rather difficult to form conceptions on this score due to the lack of proper quantitative data. For this reason, it is deemed important to investigate the coordination properties of the motor system using a standard set of test movements and methods of quantitative analysis.

We submit here the results of testing the effect of immersion on movements of the programmed type.

Methods

Two variants of 7-day immersion were used to produce weightlessness. In one of them, there were mixed factors (1st group): 3 subjects spent the

daytime 12 h in water and 12 h at night in bed in antiorthostatic position (-6° tilt of head end); in the other (2d group) there was "pure" immersion, i.e., for all 7 days the subjects (8) were submitted to immersion produced by the method of "dry" submersion developed by Ye. B. Shulzhenko and I. F. Vil-Vilyams [11].

The model movements we used were those reproduced to perform tests for identification of muscular exertion. This test, which is used in clinical practice to assess diverse motor disturbances, has undergone intensive experimental development recently, the results of which demonstrated convincingly the programmed nature of performed movements [1, 2, 5, 15]. According to the test conditions, the subjects performed a series of isometric plantar flexions of one leg with successively increasing force, from minimal to submaximal, with minimal difference in intensity of subsequent movements. The magnitude of developed exertion did not exceed 50-60 kg in our studies, which was due to our investigation conditions. However, this restriction could not contribute substantial changes in the results since, as shown by preliminary studies, precision of movements is lost at greater levels of exertion.

The tested foot was securely fixed on supports, which kept the limb in a position where the angles in the hip and knee joints constituted about 120° and in the ankle, 90° (Figure 1), in order to standardize the conditions and reduce the possibility of involvement in the movements of muscles other than crural ones, and to assure isometry.

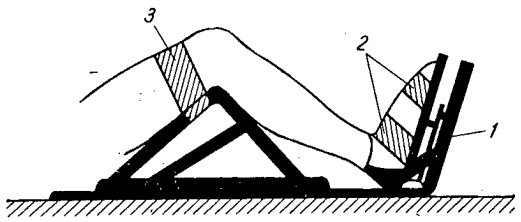


Figure 1.
Diagram of mechanical part of experimental set-up
1) strain gage
2,3) straps immobilizing foot and thigh

In the course of the test, we recorded exertion and the electromyogram (EMG) of the lateral gastrocnemius (LG) (Figure 2). We used for recording the EMG superficial electrodes 5 mm in diameter at a distance of 3.5 cm from one another and an Autogen (United States) electromyograph which has a built-in unit for integration of the EMG with a time constant of 100 ms. Exertion was recorded with a strain gage situated on the pedal, a UT-1 strain amplifier and N-338 automatic recorder.

The motor task consisted of two variants: in the first variant (test 1), movements were performed with relaxed muscles of the nonworking leg; in the second variant (test 2), it was necessary to maintain constant isometric contraction of the LG of the other leg, graded by the EMG signal. The magnitude of the signal was preset by the experimenter in digital terms on the galvanometer of the EMG integration unit, and it constituted 25 μV in the series of mixed immersion and 10 μV with pure immersion, which corresponded to 15 and 5% of maximum voluntary exertion. The subjects reproduced the specified muscular tension upon command, holding the pointer of the galvanometer in the required position.

Tests were performed before, on the 1st, 3d and 5th days of immersion on the 1st group and on the 3d and 5th days on the 2d.

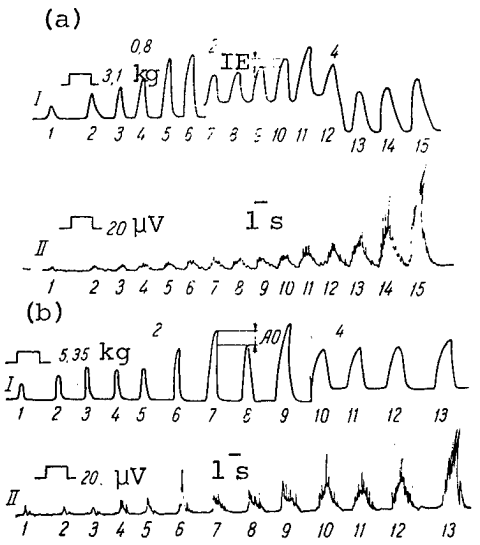


Figure 2.
Example of tracing of exertion (I) and integrated EMG (II) when performing test 1 movements (subject P.V.) in baseline period (a) and during immersion (b)
0.8, 2, 4) amplification index (AI) of recorder; calibration of exertion: a--for AI=0.8, b--AI=2
IE) increment of exertion
AO) amplitude of error

In the course of analysis, we determined several parameters characterizing precision and coordination structure of movements. It had been shown in several works that the minimal exertion and mean amplitude of exertion increment (see Figure 2), which are analogues of absolute and differential thresholds, respectively, of sensory systems [1, 2, 5, 11], are the most informative characteristics of precision of performance of this motor task. Parameters of precision of function of this control system also include the number of gradations of exertions effected by the subjects and mean amplitude of erroneous movements, i.e., equal or of less strength than the preceding movement. The relationship between subjectively assessed increment and its true value is some indication of precision (Figure 3). The coordination structure of movements was examined by their time parameters: duration of EMG bursts and time of EMG build-up to a maximum. We analyzed individual and group values of the above parameters and determined the statistical reliability of differences between sets before and after immersion. In the 1st group, we did not determine the number of gradations of exertion, absolute threshold and mean duration of movements because of the differences in the test (the subjects did not start a series of movements from the threshold).

Results and Discussion

Before immersion, all of the subjects performed the motor task well: test movements were rhythmic at a frequency of about 1 per 2 s; in a series of movements, each successive one exceeded the preceding one in exertion and amplitude of EMG (see Figure 2). Accuracy of test performance was manifested by a high degree of correlation between subjectively gaged exertion (sequential number of movement) and its actual value (amplitude of movement), and the coefficient of correlation was always close to 1.

The characteristics of test movements differed significantly in the subjects, but the group values were rather close. In this regard, the data for the larger 2d group were particularly graphic. As can be seen in the Table, this group of subjects differed within 50 kg in an average of 16.5 gradations, mean minimal exertion constituting 2.24 kg/ Mean increment of exertion (MIE), which characterizes the differential threshold of the system, constituted

about 2.80 kg in a series of movements, with mean error of 11%. Before immersion, erroneous movements constituted 14%. Error ranged from 0 to 6 kg, but in most cases did not exceed 2 kg.

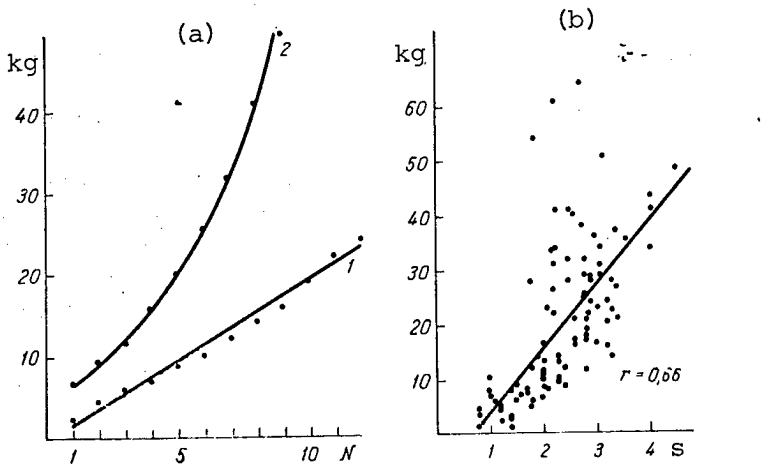


Figure 3. Amplitude of movement as a function of sequential number in series (a) and duration (b) in test 1

a) x-axis, sequential number of movement; y-axis, exertion (kg)
   1) baseline
   2) 3d day of immersion
b) x-axis,duration of EMG burst (s); y-axis, exertion (kg; baseline data)

Characteristics of movements in tests 1 and 2 before immersion and on 3d day of immersion

Time of examination	Group	Test	Mean number of gradations	Minimal exertion kg	MIE, kg	MAE, kg
Before immersion	1	1	—	—	2,79±1,01	0,60±0 28
		2	—	—	5,49±0,88	4,09±0,58
	2	1	16,50±1,94	2,24±0,54	2,80±0.31	1,16±0,59
		2	11,63±1,37	3,63±0,69	3,73±0,53	1.34±0,49
Immersion, 3d day	1	1	—	—	6,78±1,62	3,02±1,39
		2	—	—	7,16±0,45	5,67±0,49
	2	1	9,33±0,61	6,03±1,49	6,14±0,54	3,37±2,40
		2	10,33±1,26	5,14±1,42	5,43±1,33	1,84±0,25

Note: Dash signifies that parameters were not determined.

The duration of EMG bursts during test movements changed from 0.35 to 4.10 s, showing a close correlation with exertion: the coefficient of correlation in the group for a set of 92 movements was 0.66 (Figure 3).

In test 2, where there was concurrent specified contraction of muscles in the other leg, precision of performance of the main task (build-up of exertion) diminished reliably: the number of gradations in a series of movements decreased, threshold exertion and increment of exertion increased, and there was increase in amplitude of error (see Table, Figure 4). In the 1st group of subjects, there was particularly significant decline in precision of test performance, which was apparently due to a higher level of specified contraction of the opposite leg's LG.

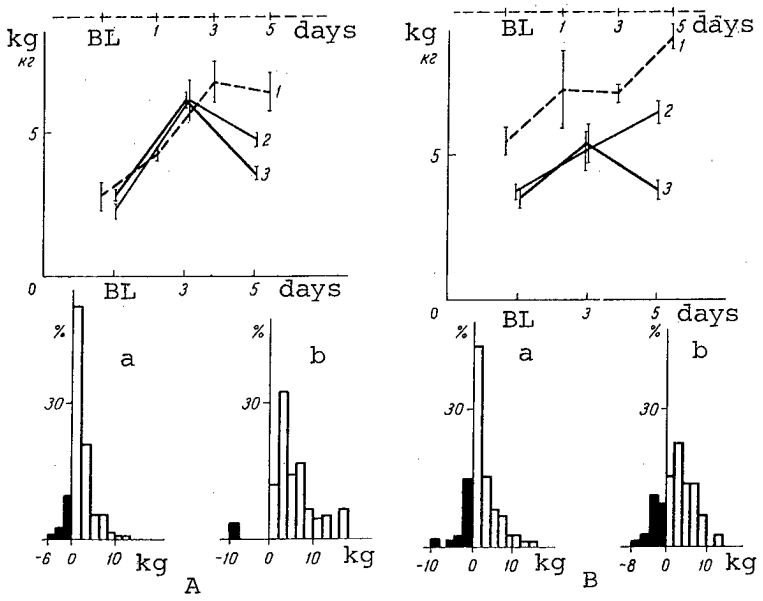


Figure 4. Change in precision of movements during immersion

A) test 1, B) test 2
At the top, change in mean increment of exertion (curves 1, 3) and minimum exertion (curve 2) during immersion. X-axis, test day; y-axis, exertion (kg); dash line--combined immersion, solid line--day of immersion. Bottom: histograms of distribution of exertion increment (kg); x-axis, magnitude of change in exertion (kg); y-axis, number of changes in this parameter (%). White bars--increase in exertion, black--decrease (errors). a) before immersion, b) during immersion, BL--baseline

Immersion did not affect ability to perform the task: all of the subjects coped well with it (see Figure 2). Quantitative analysis of movements, however, revealed a substantial decline of their precision characteristics. This was manifested by a decrease in total number of differentiated exertions, increase in absolute and differential thresholds, increase in mean amplitude of error (MAE). The changes caused by immersion were particularly distinct on its 3d day. As can be seen in Figure 4, MIE for the group on the 3d day of combined immersion constituted 6.78 kg (versus 2.79 kg before immersion), and MAE reached 3.02 kg (versus 0.6 kg before immersion; see Table). On the 3d day of immersion, 6 subjects in the 2d group showed a decline to almost one-half in mean number of gradations; threshold exertion, MIE and MAE increased by more than double (see Table and Figure 4). All of the changes mentioned were reliable.

The direction of changes elicited by immersion were analogous in performance of test 2 (see Figure 4), and their dynamics in both groups were similar: the changes reached a maximum on the 1st-3d day of immersion, and thereafter showed a tendency toward evening out. However, an increase in some of the test 2 characteristics was also observed on the 5th day (see Figure 4, curves 1 and 2). While there was the same general direction of changes, the magnitude of change in precision characteristics of movements was distinctly lower in test 2 during immersion than in test 1: threshold, MIE and MAE in movements of test 1 increased by more than 2 times, whereas in test 2 these parameters did not exceed 50% (see Table).

Immersion also led to change in structure of movements. Analysis of time characteristics revealed changes in mean duration of EMG bursts and in relationship between amplitude of movements and its duration. But these changes were in different directions in different subjects.

Briefly summarizing our results, it can be concluded that immersion did not elicit profound changes in program mechanisms, but did impair appreciably the precision qualities of the control system. The decrease in precision of performance of the motor task was manifested by a reliable decrease in number of distinguished gradations of exertion, increase in absolute and differential thresholds, increase in amplitude of erroneous movements. These changes were distinctly manifested under all experimental conditions: in the combined and pure immersion experiments, when performing the task with one leg and with concurrent use of the other (tests 1 and 2). The universality and consistency of changes wereindicative of their relation to immersion, while the speed of their development was indicative of their reflex nature.

As shown in [17], removal of static load, which occurs during immersion, causes marked (by 40% or more) attenuation of tonus of the posterior crural muscle group. It reaches a maximum by the 2d-3d day of immersion, i.e., at the same time as the maximum changes in precision of movements in our experiments. Apparently, the decline of muscle tone could alter appreciably the precision capabilities of the motor system. In this case, primarily changes in condition of the muscular periphery may be the source of error, which are not taken into consideration by program mechanisms, as a result of which a situation is created, in which there is inconsistency between the command and properties of the effector system. Another factor involved in reduction of precision of control in the presence of atonia could be a decrease in afferent influx required for construction of a precise command and to maintain in a normal range the state of central mechanisms. The decreased activity of static input inherent in immersion and hypokinesia is supplemented, in the case of atonia, by decrease in muscular afferentation due to unloading of muscular receptors. Apparently, the condition of the central nervous system by the 3d day of immersion hypokinesia can be interpreted as a state of partial deafferentation.

Denervation effects in systems of motor control have not been sufficiently investigated. However, it is known that one of the consistent sequelae of denervation is substantial lowering of thresholds of sensitivity to stimuli, as well as to "alien" stimuli [7]. In the opinion of L. A. Orbeli, the latter is due to inadequacy of the level of autogenic inhibition normally mediated by signals from muscular receptors. Studies of parameters of

involvement of tendinal (Achilles) reflex and its receptorless analogue, the H reflex, under immersion and hypokinesia conditions, revealed changes in parameters of responses indicative of marked increase in excitability of spinal mechanisms [6, 17]. It appears important to mention that the dynamics of these changes were similar to those of development of coordination changes.

The hypothesis that there is a link between precision disturbances in the absence of static load and decrease in afferent influx is also confirmed by the similarity of changes in characteristics of model movements caused by immersion and partial deafferentation as a result of ischemia of the limb [2], as well as damage to cerebellospinal pathways and intermediate sections of the cerebellum (Friedreich's disease), i.e., structures related to transmission and processing of information from articular, cutaneous, muscular and other proprioceptors [1].

Within the framework of this conception, the fact we demonstrated here of preventive effect of muscular tension of the other leg (test 2), as manifested by decrease in severity of immersion-caused changes becomes understandable, whereas before immersion introduction of an additional task was consistently associated with substantial decline of precision of movements. It can be assumed that this preventive effect is related to partial correction of deficient tonic afferent influx, which is required for normal function of the control system. G. Holmes observed analogous improvement of motor characteristics with use of arm weights by patients with functional disturbances of the cerebellum [14].

BIBLIOGRAPHY

1. Artemyeva, Ye. N., in "Neyronnyye mekhanizmy integrativnoy deyatelnosti mozzhechka" [Neuronal Mechanisms of Integrative Activity of the Cerebellum], Yerevan, 1979, pp 196-201.

2. Idem, in "Fiziologicheskiye osnovy upravleniya dvizheniyami" [Physiological Bases of Control of Movements], Moscow, 1980, pp 3-11.

3. Gurfinkel, V. S., Paltsev, V. I., Feldman, A. G. et al., in "Problemy kosmicheskoy biologii" [Problems of Space Biology], Moscow, 1969, Vol 13, pp 143-161.

4. [omitted in source]

5. Yegorov, A. D., Kakurin, L. I., Pervushin, V. I. et al., in "Mozg i dvizheniye" [The Brain and Movements], Yerevan, 1973, p 52.

6. Zalkind, M. S., in "Fiziologicheskiye i biokhimicheskiye kharakteristiki skorostno-silovykh i slozhno-koordinirovannykh sportivnykh dvizheniy" [Physiological and Biochemical Characteristics of Speed-Strength and Complexly Coordinated Movements in Sports], Moscow, 1976, pp 125-126.

7. "Kosmicheskiye polety na korablyakh 'Soyuz.' Biomeditsinskiye issledovaniya" [Spaceflights Aboard Soyuz Series Craft. Biomedical Research], Moscow, 1976.

8. Kunstman, K. I. and Orbeli, L. A., IZV. NAUCH. IN-TA IM. P. F. LESGAFTA, 1924, Vol 9, pp 187-194.

9. Chekirda, I. F., Yeremin, A. V., Stepanov, V. I. et al., KOSMICHESKAYA BIOL., 1974, No 4, pp 48-51.

10. Cherepakhin, M. A., Ibid, 1969, No 2, pp 45-69.

11. Chkhaidze, L. V., "Koordinatsiya proizvolnykh dvizheniy cheloveka v usloviyakh kosmicheskogo poleta" [Coordination of Man's Voluntary Movements in Spaceflight Conditions], 2d ed., Moscow, 1968.

12. Shulzhenko, Ye. B. and Vil-Vilyams, I. F., KOSMICHESKAYA BIOL., 1976, No 2, pp 82-84.

13. Yuganov, Ye. M., Kasyan, I. I., Gurovskiy, N. N. et al., IZV. AN SSSR. SER. BIOL., 1961, No 6, pp 897-904.

14. Beckh, H. J. A., J. AVIAT. MED., 1954, Vol 25, pp 235-241.

15. Holmes, G., BRAIN, 1939, Vol 62, pp 1-30.

16. Koslovskaya, I. B., Kreidich, Yu. V., Oganov, V. S. et al., ACTA ASTRONAUT., 1981, Vol 8, pp 1059-1072.

17. Koslovskaya, I. B., Aslanova, I. F., Grigorieva, L. S. et al., PHYSIOLOGIST, 1982, Vol 25, Suppl, pp S49-S53.

UDC: 629.78:612.824-08

CEREBRAL CIRCULATION AND OXYGENATION IN HEALTHY MAN DURING GRADED EXERCISE IN ANTIORTHOSTATIC POSITION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 9 Oct 84) pp 32-34

[Article by V. Ye. Katkov and N. V. Pravetskiy]

[English abstract from source] Eleven healthy male test subjects performed exercises of 600 kgm/min (98 W) for 20 min in the head-down position (-15°). A day before exercises they were catheterized, with catheters implanted into the internal jugular vein and brachial artery. It was shown that exercises in the head-down position led to an increase in cerebral circulation, a decrease in oxygen utilization and a decrease in jugular pressure. CO_2 tension in arterial blood and blood outflowing from the brain remained comparatively stable, while base deficiency and buffer capacity decreased by a similar value.

[Text] Graded physical exercise (GPE) differing in intensity is used in space medicine to assess the functional state of the cardiovascular system and as a means of preventing the adverse effects of weightlessness. Weightlessness can have an appreciable influence on intracranial hemodynamics; however, no previous evaluations have been made of the effect of GPE on cerebral circulation under hypogravity conditions.

Our objective here was to investigate the effect of GPE on cerebral hemodynamics and metabolism in the presence of gravitational redistribution of blood in a cranial direction.

Methods

These studies were conducted on 11 healthy male volunteer subjects (mean age 33.9 years, height 177.4 cm, weight 81.6 kg) who had undergone a thorough examination. The test with GPE was performed in antiorthostatic position (-15°) on a bicycle ergometer, 600 kg-m/min (98 W) for 15 min. One day before GPE, we implanted catheters into the superior bulb of the jugular vein (JV) and brachial artery in a hospital under roentgenological control. Blood pressure was measured with electric manometers, which were secured on the level of the tips of the catheters, and recorded on a Mingograph-82

Effect of GPE on pressure in JV and ABB of blood flowing from the brain

Parameter studied	Statistical param.	At rest	With GPE
pH (JV)	$X \pm m$	7,374±0,1118	7,340±0,0135
	max-min	7,438—7,326	7,379—7,260
($n=9$)	Δ	—0,5 %*** (+8,1 % абс.)	
pCO_2 (JV), mm Hg	$X \pm m$	44,2±1,183	43,4±1,365
	max-min	49,6—36,8	49,2—37,6
($n=9$)	Δ	—1,8 %	
pO_2 (JV)	$X \pm m$	32,4±0,875	35,7±1,410
	max-min	36,4—27,3	43,9—31,3
($n=9$)	Δ	+10,1 %*	
BE (JV), mmol/ℓ	$X \pm m$	—0,2±0,493	—2,8±0,858
	max-min	2,2—2.6	0,3—6,6
($n=9$)	Δ	—2,6****	
BB (JV), mmol/ℓ	$X \pm m$	47,8±0,505	45,1±0,861
	max-min	50,2—45,3	48,3—41,3
($n=9$)	Δ	—5,6 %****	
HbO_2 (JV), %	$X \pm m$	60,0±1,601	64,1±2,116
	max-min	67,8—51,6	72,6—57,8
($n=9$)	Δ	+6,8 %*	
bO_2 (JV), mℓ	$X \pm m$	12,6±0,345	13,5±0,4448
	max-min	14,2—10,8	15,3—12,1
($n=9$)	Δ	+7,1*	
$AVDO_2$ (brain), mℓ	$X \pm m$	7,8±0,356	6,9±0,495
	max-min	9,3—6,1	8,5—4,8
($n=9$)	Δ	—11,5*	
CUO_2 (brain), %	$X \pm m$	38,1±1,725	33,9±2,347
	max-min	46,3—30,8	41,3—23,9
($n=9$)	Δ	—11,0*	
JVP_m, mm Hg	$X \pm m$	13,1±1,086	10,8±0,937
	max-min	18,5—8,0	16,0—7,0
($n=11$)	Δ	—17,6**	

*P<0.05 **P<0.02 ***P<0.01 ****P<0.01

automatic recorder. Parameters of acid-base balance (ABB) were determined using an AVL-940 automatic gas analyzer and hemoglobin, with a Hemolux instrument. The obtained results were submitted to mathematical processing on a programmable microcalculator; we used Student's criterion for variants related in pairs for statistical analysis [1].

Results and Discussion

The Table lists parameters of ABB, oxygenation of blood from superior bulb of jugular vein and pressure in this region at rest and during GPE.

Since 80-90% of all blood normally flows from the brain via the internal JV, one can assess overall gas homeostasis in the brain from the results of biochemical analysis of blood taken from this region.

A comparison of blood flowing to and from the brain revealed that changes in oxygenation parameters are the most typical for blood from the JV: pO_2, oxygenation of hemoglobin (HbO_2) and amount of oxygen contained in blood (bO_2). The changes in other parameters were the same as in arterial blood. At the same time, we should mention the constant pCO_2 level in both arterial blood and blood flowing from the brain.

Stability of CO_2 concentration during GPE is a distinctive feature of ABB of blood flowing from the brain in the JV, i.e., cerebral blood flow is controlled by the pCO_2 (JV) constant; at the same time, the concentration of oxygen in it grows in the presence of unchanged concentration in arterial blood (ΔpO_2(JV) = +10.1%, ΔHbO_2%(JV) = +6.8%, ΔbO_2(JV) = +7.1%). Against such a background, O_2 utilization by brain tissues decreases by 11.0%.

←Key: $AVDO_2$(brain)--arteriovenous difference for oxygen in the brain
CUO_2--coefficient of oxygen utilization for the brain
JVP_m--mean pressure in JV

On the basis of the principle of Fick, it can be assumed that cerebral circulation increases by at least 12% during GPE in antiorthostatic position. The pressure drop in the internal JV can serve as an indirect confirmation of this [3]. The increase in cerebral blood flow was associated with decline of O_2 utilization by the brain; however, it was adequate to the metabolic demands of brain tissues, since the base deficiency in blood from the JV (BE) and alkaline buffer capacity (BB) in blood from the JV changed just like they did in arterial blood.

Blood gases (CO_2 and O_2) may have an appreciable influence on cerebral circulation. For example, in the case of arterial change in pCO_2 (which is observed with some forms of pathology and during heavy exercise), control of cerebral circulation is redirected to this parameter [4, 5, 9, 12, 13]. However, with pathological changes in concentration of oxygen in arterial blood, cerebral circulation changes in accordance with change in arterial pO_2 [4, 5, 8, 9], since the range of resistance to hyperoxia and hypoxia is extremely narrow in brain tissues [2]. Moreover, with decline of pO_2 in the human JV to less than 28 mm Hg, there is triggering of control of cerebral circulation for this parameter [7]. At the same time, the concentration of O_2 in the JV may depend on intraregional redistribution of blood flow [10, 11]. These variants of control of cerebral circulation most probably operate through change in pH of interstitial fluid, which affects contractility of the vascular wall and does not depend on arterial pH changes [4, 6, 9].

Thus, GPE in antiorthostatic position leads to increase in cerebral circulation, decrease in utilization of O_2 by the brain and drop in JV pressure. CO_2 tension in arterial blood and blood flowing from the brain during GPE remained relatively stable, whereas BE and BB decreased to about the same extent.

BIBLIOGRAPHY

1. Urbakh, V. Yu., "Statisticheskiy analiz v biologicheskikh i meditsinskikh issledovaniyakh" [Statistical Analysis in Biological and Medical Investigations], Moscow, 1975.

2. Folkow, B. and Neil, E., "Circulation," Moscow, 1976.

3. DuBois, A. B., ANESTHESIOLOGY, 1962, Vol 23, p 473.

4. Emerson, T. E., Jr. and Parker, J. L., in "Cerebral Circulation and Metabolism," Berlin, 1975, pp 10-13.

5. Greenberg, G. H., Reivich, M. and Noordergraaf, A., FED. PROC., 1974, Vol 33, p 314.

6. Gregg, D. E., Hawthorne, E. W., Permutt, S. et al., "Physiology in Space," Moscow, 1972, pp 41-66.

7. Grote, J., TRIANGLE, 1974, Vol 13, pp 165-172.

8. Lambersten, C. J., Kough, R. H., Cooper, D. Y. et al., J. APPL. PHYSIOL., 1953, Vol 5, pp 471-486.

9. Lassen, N. A., CIRCULAT. RES., 1964, Vol 15, p 201.

10. Lubbers, D. W., in "Brain and Heart Infarct," Berlin, 1977, pp 30-32.

11. Paulson, O. B., REV. MED. (Paris), 1973, Vol 14, pp 2911-2920.

12. Poorvin, D. W. and Frankel, H. M., AMER. J. PHYSIOL., 1974, Vol 226, pp 670-674.

13. Woodbury, D. M. and Karler, R., ANESTHESIOLOGY, 1960, Vol 21, p 686.

UDC: 612.215.014.477-064

FORCED EXPIRATION PARAMETERS IN HEALTHY MAN SUBMITTED TO SIMULATED WEIGHTLESSNESS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 15 Oct 84) pp 34-37

[Article by N. M. Asyamolova, V. G. Shabelnikov, V. M. Baranov, A. N. Kotov and M. Yu. Volkov]

[English abstract from source] Lung volumes and forced expiratory volumes during 3-hour water immersion as well as in the upright and supine positions were measured. Water immersion up to the neck decreased the functional residual capacity, peak and maximum velocities of air flows during inspiration and expiration with various lung volumes and increased the forced expiratory time and pulmonary time constant. These changes seem to be produced by a higher inelastic resistance as well as by additional hydrostatic pressure upon the chest and abdomen. During the transfer from the upright to the supine position these changes were identical but of smaller magnitude.

[Text] Changes in position of the body from erect to horizontal and immersion in water are, as we know, associated with reduction of lung volumes and impairment of mechanics of respiration [1-3, 5-9, 10, 11, 14, 15].

The forced expiration test, which has gained use essentially in clinical practice, is a simple, noninvasive method of assessing the mechanical properties of the lungs [4, 12, 13]. However, this method has not been used as yet to its full extent in applied physiology.

Our objective here was to analyze the informativeness of parameters of forced expiration as related to postural factors and water immersion simulating the effects of weightlessness [1, 8].

Methods

A total of 4 healthy men 25-30 years of age, weighing 65-90 kg, participated in the studies.

Measurements were taken in erect, supine positions and during immersion in water up to the neck in erect position.

The forced expiration test was performed twice (on different days) 15 min after staying in each position, as well as in the 1st, 2d and 3d h of water immersion and in supine position. Forced expiration was performed by the conventional method [12, 13] on an automated Pneumoscreen-2 pneumotachograph of the E. Yaeger firm (FRG), which records spirograms and "flow-volume" loops with visual monitoring on a display, as well as computes 33 volume-velocity parameters [4, 5, 7]. We used a Dataspir computer to accumulate data and for statistical processing. Nominal parameters were calculated according to Knudson [13].

Residual lung volume was measured by the helium method using an M-100 mass spectrometer of the McCoy Company (United States) [5, 7].

Results and Discussion

Figure 1 illustrates the results of measuring static lung volumes. There was an 0.2-0.4 ℓ (3-6%) decline in total lung capacity (TLC) when changing body position (standing--supine) and immersing in water, which was within the range of margin of error of the measurement.

Immersion in water let to shift in level of functional residual capacity (FRC), increase in inspiratory reserve volume (IRV) and decrease in expiratory reserve volume (ERV). We were impressed by the fact that, during water immersion, the changes were more marked than when moviging from standing to supine position.

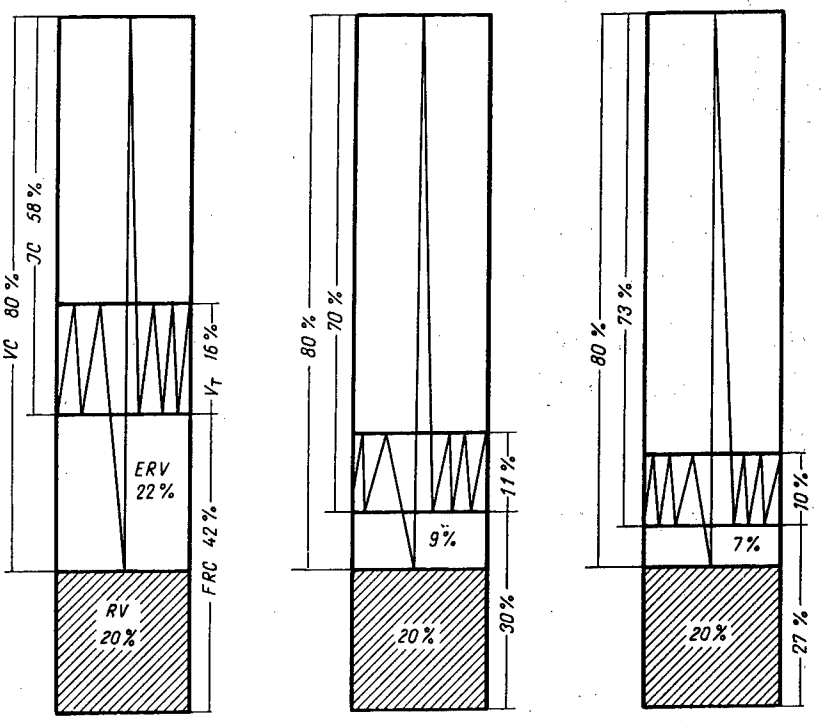


Figure 1. Structure of static lung volumes with change in body position and water immersion (% of TLC)
1, 2) standing and supine positions, respectively 3) erect in water

Evidently, changes in balance of forces exerted on the respiratory system were the cause of the observed changes in TLC components. Thus, upon immersion in water, the additional hydrostatic pressure on the surface of the rib cage and abdominal wall should elicit some additional compression of the lungs and rise of the diaphragm at the end of a quiet expiration [9]. Concurrent redistribution of blood from the lower extremities to the upper half of the body could lead to decrease in expansibility of the lungs due to increased blood in them [6, 7, 10, 16]. This could also cause decline of FRC. Analogous effects should occur with change in direction of force of weight of the lungs and viscera after changing to supine position [3, 5, 15].

Dynamics of parameters of forced expiration in healthy men with change in body position and during water immersion (M±m) n = 8

Parameter	Knudson nominal values	Standing (15 min)	Supine (15 min)	Water immersion	
				15 min	3 h
TLC, ℓ	—	6,9±0,33	6,7±0,34	6,8±0,22	6,7±0,33
FVC, ℓ	4,1	3,8±0,19	3,6±0,19	3,4±0,13	3,3±0,15*
PEF, ℓ/s	9,6	10,2±0,45	9,3±0,25	8,8±0,43*	8,7±0,46*
MEF75, ℓ/s	8,9	7,7±0,56	7,7±0,44	7,6±0,38	7,1±0,65
MEF50, ℓ/s	6,4	5,5±0,66	4,9±0,42	3,9±0,23*	3,9±0,26*
MEF25, ℓ/s	3,3	2,0±0,15	1,8±0,21	1,6±0,17	1,5±0,10*
PIF, ℓ/s	—	9,1±0,66	8,2±0,39	7,3±0,36*	7,0±0,44*
MIF, ℓ/s	—	8,6±0,49	7,6±0,37*	6,5±0,45*	6,4±0,44*
MTT	0,66	0,61±0,07	0,61±0,05	0,69±0,06	0,74±0,06
TE, s	—	2,2±0,27	2,4±0,21	2,9±0,13	3,0±0,2
A_{EX}, ℓ^2/s	33,5	25,7±2,73	22,4±2,44	20,6±0,94	19,4±1,33*

* $P \leq 0,05$.

The Table lists the results of forced expiration tests. Immersion in water led to 15 and 20% decline in peak velocity of inspiratory flow (PIF) and expiratory flow (PEF), respectively, as compared to erect position. There was concurrent decline of maximum velocity of expiratory (MEF) and inspiratory (MIF) flow on different levels of vital capacity of the lungs: MEF50 and MEF25 by 20%, MIF50 by 25%. For this reason, there was reliable decrease in area under the flow-capacity curve (A_{EX}) with unchanged expiratory volume (FVC).

The dynamics of flow characteristics with change from erect to supine position presented the same direction, but the changes were less marked. The extent of change was consistent with data in the literature [12].

The individual shapes of flow-volume curves obtained for different subjects with change in body position and after immersion in water showed virtually no change (Figure 2).

Analysis of time characteristics of parameters of forced expiration showed some delay in emptying of the lungs during water immersion, which was manifested by decline of 1-s vital lung capacity (FVC_1) by 16%, 27% increase in duration of forced expiration (TE) in the 15th min and by 36% by the end of

the 3d h of immersion. Concurrently there was an increase in time constant of the lungs (MTT) by 21%.

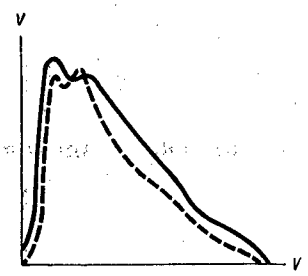


Figure 2.
Flow-volume curve for subject V. in 3d h of water immersion
Solid line--erect in room, dash line--erect in water

The changes in time and volume at peak expiratory flow were in different directions in different subjects.

Thus, during water immersion we observed decline of maximum velocities of air flow in forced inspiration and expiration. The parameters of forced expiration presented a tendency toward further decline in the course of 3-h immersion, but this decline was unreliable.

A distinctive feature of the test with forced expiration is that, after reaching a maximum, the expiratory flow ceases to depend on pleural pressure and does not react to increasing exertion of respiratory muscles. For this reason, additional compression of the lungs when a man submerges in water should also not have affected parameters of forced expiration. The slower forced emptying of the lungs observed in our studies is most likely attributable to the mechanical properties of the lungs due to an increase in blood volume in them and impairment of configuration of the tracheobronchial tree [7, 8, 10], rather than to change in force applied to the lungs.

Since the lung time constant, which equals, as we know, the product of airway resistance (R) multiplied by expansibility of the lungs (C), increased, we could have expected rise in R or C. However, we know that intensification of blood supply to the lungs leads to decrease in their expansibility [6, 9, 14, 15]. For this reason, our data warrant the assumption that there is an increase in airway resistance during water immersion. This hypothesis is consistent with data in the literature concerning an increase in R by 65-80% with immersion and about 20% decrease in C [6, 14].

The increase in R should indicate changes in medium-sized bronchi, which determine mainly nonelastic resistance to respiration [4, 12].

Thus, our findings revealed that, as compared to erect position on land, the same position in water elicits a noticeable decline of velocity of forced expiration and inspiration apparently due to increased resistance of central or middle airways. The parameters of forced expiration in supine position underwent analogous change, but to a lesser extent.

BIBLIOGRAPHY

1. Genin, A. M. and Sorokin, P. A., in "Dlitelnoye ogranicheniye podvizhnosti i yego vliyaniye na organizm cheloveka" [Prolonged Restriction of Movement and Its Effect on Man], Moscow, 1969, pp 9-16.

2. Golovkina, O. L., KOSMICHESKAYA BIOL., 1982, No 3, pp 43-46.

3. Katkovskiy, B. S. and Andretsov, V. A., KOSMICHESKAYA BIOL., 1972, No 4, pp 55-59.

4. Kuznetsova, V. K., in "Rukovodstvo po klinicheskoy fiziologii dykhaniya" [Manual of Clinical Physiology of Respiration], Leningrad, 1980, pp 37-108.

5. Nikolayenko, E. M., Katkov, V. Ye., Gvozdev, S. V. et al., KOSMICHESKAYA BIOL., 1983, No 6, pp 39-43.

6. Tikhonov, M. A., Ibid, 1972, No 6, pp 52-56.

7. Tikhonov, M. A., Kondakov, A. V., Asyamolova, N. M. et al., Ibid, 1983, No 1, pp 37-40.

8. Shulzhenko, Ye. B., "Physiological Effects of Altered Gravity (Model Land-Based Experiments)," doctoral dissertation in medical sciences, Moscow, 1975.

9. Agostoni, E., PHYSIOL. REV., 1972, Vol 52, pp 57-128.

10. Bondi, K. R., Young, J., Bennet, R. M. et al., J. APPL. PHYSIOL., 1976, Vol 40, pp 736-740.

11. Castile, R., Mead, J., Jackson, A. et al., Ibid, 1982, Vol 53, pp 1175-1183.

12. Cherniack, R. M., "Pulmonary Function Testing," Philadelphia, 1977.

13. Knudson, R. J., Slatin, R. C. and Lebowitz, M. D., AMER. REV. RESP. DIS., 1976, Vol 113, pp 587-600.

14. Milic-Emili, J. and Ruff, F., BULL. PHYSIO-PATH. RESPIRAT., 1971, Vol 7, pp 1181-1196.

15. Sasaki, H., Hida, W. and Takishima, T., J. APPL. PHYSIOL., 1977, Vol 42, pp 706-710.

UDC: 612.766.2-088.1:612.124:577.112.382.3

EFFECT OF RESTRICTED MOTOR ACTIVITY ON ALANINE LEVEL IN HUMAN PLASMA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 19 Dec 84) pp 37-40

[Article by T. F. Vlasova, Ye. B. Miroshnikova and A. S. Ushakov]

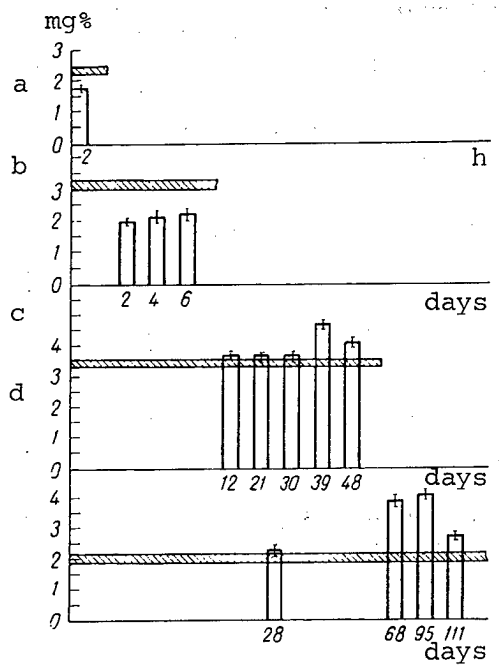
[English abstract from source] The plasma alanine concentration was measured in 28 healthy male test subjects exposed to head-down tilt of various duration (2-hour exposure at -12°, 7-day exposure at -6°, 49-day exposure at -4°, and 120-day exposure at -4°). Head-down tilt led to alanine changes that correlated with exposure time. These results suggest that alanine concentrations in blood reflect to a certain extent the rate of hepatic gluconeogenesis and depend significantly on the hypokinetic time. The findings can be clinically used as a measure of hepatic gluconeogenesis in bed-ridden patients that may require preventive or therapeutic treatment.

[Text] Differentiated changes occur in parameters of amino acid metabolism when motor activity is restricted, and they are related to duration of the test period, there being a specific amino acid status corresponding to each time period [1-4, 6-8, 19]. The changes demonstrated in amino acid metabolism under hypokinetic conditions are, according to results obtained by direct and indirect methods, primarily due to slower synthesis of tissue proteins [9-12, 17]. Protein synthesis is effected by including in biosynthetic processes the components of free amino acids. For this reason, investigation of metabolism of the latter under hypokinetic conditions is rather important in order to assess amino acid metabolism as a whole. Alanine, which is actively involved in both transamination and gluconeogenetic processes in the liver, controlling intensity of the latter, is one of the key amino acids [13-15].

Methods

Four tests were conducted under AOH [antiorthostatic] hypokinesia) conditions of different duration and with the body tilted at different angles on 28 male subjects deemed to be essentially in good health after a clinical and physiological examination: 2-h AOH (-12°, 6 men), 7 days (-6°, 8 men), 49 days (-4°, 8 men) and 120 days (-4°, 6 men). The subjects were kept in the hospital on a controlled diet. Determination of free amino acids of plasma collected from fasting subjects was made using a Liquimat III automatic

analyzer (Labotron, FRG., sensitivity 0.5-5 nmol/mℓ) [5, 18]. The samples were deproteinized with crystalline sulfosalicylic acid [16]. Venous blood was drawn once during 2-h AOH, on the 2d, 4th and 6th days of 7-day AOH, on the 12th, 21st, 30th, 39th and 48th days of 49-day AOH and on the 28th, 68th, 95th and 11th days of 120-day AOH. The data on free alanine content of plasma are submitted in the Figure in the form of bars.



Free plasma alanine level with subjects submitted to AOH
a, b, c, d) AOH-- 2 h (-12°), 7 days (-6°), 42 days (-4°) and 120 days (-4°).
Crosshatched bars--baseline

Results and Discussion

Analysis of the findings revealed that AOH elicits specific changes in plasma alanine levels in the subjects as a function of duration of hypokinesia. The 2-h AOH conditions led to reliable decline of plasma alanine level (the deviation constituted -0.5 mg%). With 7-day AOH, there was decline in concentration of alanine throughout the test period. The deviations from base levels within the test period constituted -1.17, -1.00 and -0.95 mg% on the 2d, 4th and 6th days, respectively. The plasma alanine decline also affected total free amino acid content, which decreased with both 2-h and 7-day AOH. Recovery from the amino acid imbalance following 2-h AOH occurred almost immediately after termination of the experiment. In the case of 7-day AOH, we did not observe normalization of amino acid balance. Conversely, extension of AOH to 49 and 120 days led to accumulation of alanine in blood. Already on the 12th day of 49-day AOH there was gradual build-up of plasma alanine to +0.26 mg% of base status. The deviations reached +0.25, +0.24, +1.3 and +0.71 mg% on the 21st, 30th, 39th and 48th days, respectively. Alanine concentration was at a maximum on the 39th day. Changes in the same direction in blood alanine content were demonstrated in the subjects during 120-day AOH. There was gradual accumulation of alanine in blood starting on the 28th day to the end of the test, with a maximum on the 95th day. The increases in concentration during 120-day AOH constituted +0.25 mg% on the 28th day, +0.84 mg% on the 68th day, +2.13 mg% on the 95th day and +0.77 mg% on the 111th day, as compared to base status. There was no recovery of amino acid balance in the post-AOH observation period, which lasted 2 weeks, following both 49- and 120-day AOH.

In summary of the findings, it can be concluded that brief AOH (up to 12 days) causes a decline of plasma alanine levels in the subjects, whereas prolonged AOH (over 12 days), on the contrary, elicits a rise. The demonstrated dynamics of blood alanine levels in immobilized subjects are not a chance finding and apparently reflect changes in intensity of gluconeogenesis in the liver. Alanine holds a key position in homeostasis of gluconeogenesis

[13-15]. Synthesis of this amino acid takes place in muscle tissue by means of transfer to pyruvate of amino groups subject to deamination and oxidation of other amino acids. Then there is transfer of alanine from blood into the liver and formation of glucose there, which is transported in blood, thus forming the glucose-alanine cycle, which is important to supplying energy to the body. Under hypokinetic conditions, there is apparently change in the glucose-alanine cycle, with both brief and prolonged immobilization. At the early stages of hypokinesia, the changes are due to more intensive degradation of glycogen, which leads to hyperglycemia, and blood glucose level rises [9]. It should be assumed that with brief AOH the rate of alanine uptake by the liver exceeds the rate of its production in skeletal muscles, and for this reason hypoalaninemia develops. The latter was demonstrated and experimentally confirmed by our findings in this study.

Brief exposure to hypokinesia as a stressor elicits increased utilization of other free amino acids of protein origin, in addition to alanine. This period is characterized by decline of biosynthetic processes [10-12, 17], and for this reason there is natural increase under these conditions in requirement for free amino acids, which are a distinctive reserve of the body, involvement of which in numerous metabolic processes must increase, which is what leads to reduction of the amino acid pool. In addition, it should be noted that the changes demonstrated during 2-h AOH with regard to other amino acids were more marked than with 7-day AOH. While 7 out of 17 amino acids, including alanine, underwent change with 2-h AOH, only 3 amino acids presented a decrease in concentrations, also in the presence of drop in alanine level, in the case of 7-day AOH. This is attributable to the body's natural reaction to immobilization: with the drastic change from mobile state to rest there is activation of reaction to hypokinesia.

Thus, the early stage of hypokinesia is characterized by hypoalaninemia. The increased utilization of alanine by the liver is attributable to stimulation of the gluconeogenetic process.

At the late stages of hypokinesia (over 12 days) there is a shift in blood amino acid balance in the direction of accumulation of free amino acids due to prevalence of catabolic over anabolic processes against a background of diminished biosynthetic processes [9]. This period is characterized by an increase in concentrations of most free amino acids in blood, including alanine. In the case of prolonged immobilization of the subjects (49-day and 120-day AOH), there is developed of forced inactivity of muscles and energy requirements of the body diminish. This is associated with development of hypoglycemia (decrease in store of glycogen and inhibited de novo synthesis thereof); consequently, blood glucose level drops [9]. The latter leads to hyperalaninemia, i.e., in this period the rate of alanine production in muscles is faster than its absorption by the liver.

Thus, long-term hypokinesia leads to hyperalaninemia, while the intensity of gluconeogenesis in the liver diminishes. It should also be noted that the angle of inclination of the body during antiorthostatic hypokinesia did not have an appreciable effect on dynamics of plasma alanine levels.

Thus, the results of studying the dynamics of human plasma alanine content under AOH conditions indicate that the concentration of alanine in blood

reflects, to some extent, the intensity of gluconeogenesis in the liver. The nature of change in alanine level depends appreciably on duration of hypokinesia. The obtained data may also be used by clinicians to assess the gluconeogenetic process in man's liver during long-term bedrest, in order to subsequently correct it by a set of therapeutic and preventive measures.

BIBLIOGRAPHY

1. Bychkov, V. P., Borodulina, I. I. and Vlasova, T. F., KOSM. BIOL., 1981, No 5, pp 21-23.

2. Vlasova, T. F., Ushakov, A. S. and Miroshnikova, Ye. B., Ibid, 1978, No 4, pp 23-27.

3. Vlasova, T. F., Ushakov, A. S. and Polyakov, V. V., Ibid, 1977, No 1, pp 43-47.

4. Vlasova, T. F., Miroshnikova, Ye. B. and Kochetkova, A. N., in "Vsesoyuznaya konf. po kosmicheskoy biologii i aviakosmicheskoy meditsine. 7-ya. Tezisy dokladov" [Summaries of Papers Delivered at 7th All-Union Conference on Space Biology and Aerospace Medicine], Kaluga, 1982, Vol 1, p 78.

5. Vysotskiy, V. G., Vlasova, T. F. and Ushakov, A. S., LAB. DELO, 1973, No 9, p 567.

6. Nevolina, T. V., Polyakov, V. V. and Vlasova, T. F., in "Aktualnyye voprosy kosmicheskoy biol. i meditsiny" [Pressing Problems of Space Biology and Medicine], Moscow, 1975, Vyp 2, pp 154-155.

7. Popov, I. G. and Latskevich, A. A., KOSM. BIOL., 1984, No 3, pp 25-34.

8. Ushakov, A. S., Vlasova, T. F. and Miroshnikova, Ye. B., in "Fiziologicheskiye i klinicheskiye problemy adaptatsii cheloveka i zhivotnykh k gipotermii, gipoksii i gipodinamii" [Physiological and Clinical Problems of Human and Animal Adaptation to Hypothermia, Hypoxia and Hypodynamia], Moscow, 1975, pp 149-150.

9. Fedorov, I. V., KOSM. BIOL., 1980, No 3, pp 3-10.

10. Idem, "Obmen veshchestv pri gipodinamii" [Metabolism Under Hypodynamic Conditions], Moscow, 1982.

11. Boots, F. W., J. APPL. PHYSIOL., 1982, Vol 52, pp 1113-1118.

12. Idem, Ibid, 1979, Vol 47, pp 974-977.

13. Felig, P., METABOLISM, 1973, Vol 22, pp 179-207.

14. Felig, P., Marliss, E., Pozefsky, F. and Cahill, S., AMER. J. CLIN. NUTR., 1970, Vol 23, pp 986-992.

15. Felig, P., Pozefsky, F., Marliss, E. and Cahill, Y. F., SCIENCE, 1970, Vol 167, pp 1003-1006.

16. Gerrtisen, T., Rehberg, M. L. and Waisman, H. A., ANALYT. BIOCHEM., 1965, Vol 11, pp 460-466.

17. Goldspirk, D. F., J. PHYSIOL. (London), 1977, Vol 264, pp 267-282.

18. Spackman, D. H., Stein, W. H. and Moore, S., ANALYT. CHEM., 1958, Vol 30, pp 1190-1203.

19. Ushakov, A. S. and Vlasova, T. F., LIFE SCI. SPACE RES., 1976, Vol 14, pp 256-262.

UDC: 612.751.1.014.447-064

EFFECT OF WEIGHTLESSNESS AND SOME OF ITS MODELS ON MECHANICAL PROPERTIES OF ANIMAL BONES SUBMITTED TO TORSION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 2 Nov 84) pp 40-45

[Article by M. A. Dobelis, Yu. Zh. Saulgozis, V. Ye. Novikov, Ye. A. Ilin and V. S. Oganov]

[English abstract from source] Mechanical properties (stress and strain) of bones from rats of different ages exposed to weightlessness, hypodynamia or hypokinesia were examined upon torsion. As compared to the controls, the femur of Cosmos-1129 rats showed high deformability. Also, skeletal bones of young rats proved more sensitive to hypodynamia than those of adult animals.

[Text] A negative calcium balance in man during and after spaceflights [1, 2, 18, 21] can elicit change in bone tissue structure and worsening of its mechanical properties. The latter was demonstrated in experiments on rats aboard biosatellites of the Cosmos series [9, 10, 17].

However, the data obtained concerning change in strength characteristics of rat bones following spaceflights are somewhat contradictory, and this can be attributed to heterogeneity of tissular structure in the same bones and differences in biomechanical tests used. In particular, there is a shortage of information about bone resistance to torsion [18]. At the same time, it is known that the capacity of compact bone to withstand destruction when submitted to torsion and shear is determined to a significant extent by the amounts of minerals in tissue (per unit volume) [4]. Tangential stress, which is most probably the result of muscular contraction, may be the cause of loss of carrying capacity of the entire anisotropic structure of bone, in spite of its relatively low absolute value [5].

In view of the foregoing, we made an experimental study of mechanical properties of animal (rat) bones submitted to torsion after flight aboard the Cosmos-1129 artificial earth satellite, as well as after hypokinesia and hypodynamia.

Methods

We examined the tibia, femur and humerus of Wistar rats of different ages (2.5, 3 and 6.5 months) (Footnote 1) (The age is given at the start of the experiment) The experimental material was divided into five groups.

The 1st group consisted of animals kept in the vivarium (vivarium control), and some of them (2.5 months old) were kept in cages, while others (3 and 6.5 months old) were unrestricted. The 2d group consisted of animals kept in a mockup of an artificial earth satellite under ground-based conditions. The 3d group included animals that were deprived of support on their hind limbs ("hypodynamia" model) by keeping them in a "suspended" system [3]. The 4th group consisted of rats kept in individual box-cages that prevented movement of the body and legs ("hypokinesia" model). The 5th group consisted of animals flown in Cosmos-1129 for 19.5 days. The experiment lasted 22 days for animals 2.5 and 6.5 months old (hypodynmia and hypokinesia), about 50 days for those 3 months of age (19.5-day flight and 30-day postflight recovery on the ground). The animals 2.5 and 6 months old were kept in groups of 15, and those 3 months old in groups of 5.

After the experiments, the animals were decapitated and the isolated bone material was stored at a temperature of 4°C with continuous moistening with saline. Just before the tests, bone temperature was gradually brought up to room temperature. To assure reliable immobilization of bones in clamps of the test bench, we separated the epiphyseal parts of the bones, while the terminal segments were imbedded with rapidly hardening plastic, Noracryl-65, in cup-shaped molds, the axis of which was directed along the longitudinal axis of the sample.

The torsion tests were performed using a modified method described previously [7, 15], with a special small stand developed for this purpose [7]. The loading rate constituted 0.0011 N•m/s. Twisting moment was measured with a tensodynamometer and angle of torsion with a φ-tensometric deflectometer. The load curve was recorded on a two-coordinate PDS-0.21 potentiometer with margin of error of ±0.0011 N•m/s and ±0.0007 rad in determination of moment and angle of torsion. The obtained M-φ experimental curves were inputted in a Wang-2200 computer using a Digitizer-2262 curve digitizer for subsequent processing.

Results and Discussion

Calculation of stress and strain. In view of the irregularity of bone shape there is no precise method of determining the parameters of its mechanical properties. For this reason, we used an approximate estimate, where the bone was arbitrarily viewed as a cylinder with equal thickness of walls along the diaphysis. In this case, stress in the external bone layer is $\tau = M/W_p$, where W_p is the moment of resistance to torsion of transverse bone section. The values of W_p were established by the mathematical method of integration of areas of a complex shape.

Microphotographs of the cross-section of the central segment of the diaphysis revealed that the external and internal outlines of compact bone matter are approximated with an ellipse or circle. The final choice of approximation method was made using variance analysis of the data [6] (Table 1).

The results of analysis revealed that most of the changes in maximum stress upon torsion τ^* can be explained if using an approximation of long bone with a hollow cylinder. In this case, the experimental conditions explain 12.0% ($P<0.0002$) and the type of bone 30.1% ($P<1.10^{-6}$) of the variation of τ^*. When

approximating a bone fragment to a hollow ellipse for estimation of stress, experimental conditions are responsible for 13% of the variation ($P<0.0002$) and the type of bone, only 23.8% ($P<1.10^{-5}$). It was established that the moment of resistance to torsion W_p can, in the first approximation, be defined by a simpler method, using the intrinsic dimensions of the bone's cross-section. For this reason, we calculated stress τ in the external bone layer using the function $\tau = \frac{16MD}{\pi(D^4 - d^4)}$, where D and d are outside and inside diameters, respectively, averaged for the cross-section of the diaphysis.

Table 1. Results of variance analysis of mechanical properties of bones of animals 2.5 months old (1st, 3d and 4th groups)

Parameter	Factor influence (FI), %				Reliability of FI		
	A	B	AB	Z	A	B	AB
G^0	0,4	65,5	2,8	31,3	H	$<1\cdot10^{-6}$	<0,05
τ^*	12,0	30,1	1,0	56,9	<0,0002	$<1\cdot10^{-6}$	H
γ^*	9,0	37,4	8,1	45,5	<0,0002	$<1\cdot10^{-6}$	<0,002
V^*	13,5	10,6	8,5	67,4	<0,0002	<0,001	<0,01
G^*	0,6	76,7	2,1	20,6	H	$<1\cdot10^{-6}$	<0,03

Key: Z) unexplained factors
H) insignificant reliability ($P>0.05$)
A) upkeep conditions
B) type of bone

Relative strain γ upon twisting of a cylindrical tube made of isotropic material is calculated according to $\gamma = \frac{\varphi}{l}R$, where φ is the angle of torsion of a tube with outside radius R on base l. In our case, in view of the small thickness of the cortical wall of the bone as compared to the diameter, we are actually dealing with a thin-walled tube. Considering bone to be a quasi-isotropic material, in the first approximation strain γ of the tubular bone fragment was defined as $\gamma = \varphi D/2l$. The obtained γ-τ curves were approximated to the equation, $\gamma = A_1\tau + A_2\tau^3$, where A_1 and A_2 are numerical coefficients established by the least squares method. The modulus of shear was determined using the formula:

$$G = \left(\frac{d\gamma}{d\tau}\right)^{-1} = (A_1 + 3A_2\tau^2)^{-1},$$

and specific energy of strain by the equation:

$$U = \tau\gamma - \int_0^\tau \gamma d\tau = \frac{1}{2}\tau^2\left(A_1 + \frac{3}{2}A_2\tau^2\right).$$

Test results. The influence of upkeep conditions (factor A), type of bone (factor B) and a combination of these two factors (AB) on mechanical properties of bones in animals 2.5 months of age was evaluated by means of

variance analysis (see Table 1). It was found that factor B is responsible for more of the variations in parameters of mechanical properties than factor A. The type of bone (factor B) has the strongest influence on initial G^0 and failure causing G* of the shear modulus. For this reason, analysis of the results was made separately for each type of bone.

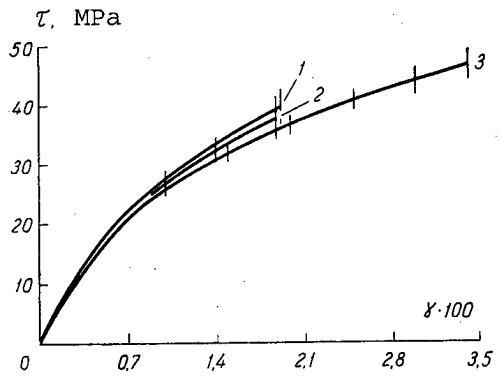


Figure 1.
Approximate mean γ-τ curves for femur of experimental animals at age of 3 months
1-3) animals in 1st, 2d and 5th groups

The γ-τ curves for the femur of animals 3 months old were the same in the 1st and 2d groups; they are both within the limits of the standard error for τ with the same values for γ (Figure 1).

Thus, we virtually failed to demonstrate a difference in values for characteristics of mechanical properties of the femur in both control groups (Table 2).

The strain curve for the femur of animals in the 5th group differs substantially from the one for control groups. Mean maximum stress τ* in the 5th group is 22.3% greater than in the 2d. Typically enough, with strain γ>0.006, the γ-τ curve for the bone of animals in the 5th group passes much lower than in the control groups (see Figure 1).

Table 2. Mechanical characteristics of femur of animals 3 months old (1st, 2d and 5th groups)

Group	Parameter	Characteristics of mechanical properties				
		G^0, GPa	τ*, MPa	γ*	U^*, kJ/m^3	G*, GPa
1	$\bar{x}$	4,18	39,6	0,0190	467	1,07
	$S_{\bar{x}}$	0,36	3,6	0,0013	63	0,11
2	$\bar{x}$	4,42	38,2	0,0186	467	1,02
	$S_{\bar{x}}$	0,21	3,9	0,0020	91	0,11
5	$\bar{x}$	4,57	46,7	0,0342	1081	0,58
	$S_{\bar{x}}$	0,32	3,0	0,0021	110	0,05

As can be seen in Figure 1 and Table 2, with increase in stress the shear modulus decreases dissimilarly in different groups of animals. The absolute values for initial shear moduli G_0 does not differ statistically in animals in the 1st, 2d and 5th groups, while the G_0/G^* ratio constitutes 7.9 in the 5th group, whereas it is 3.9 and 4.3 in the 1st and 2d groups, respectively.

We also observed significant increase (2.3-fold) of maximum specific energy of strain U* of bones in the 5th group of animals, as compared to both control groups, chiefly due to increase in maximum strain.

The results of these studies indicate that, in animals submitted to weightlessness (19.5 days) and then readapted to earth (for 30 days), the femur becomes more susceptible to torsion, as compared to the same material from control animals. At the same time, it is known [9, 10] that the mechanical strength of the femur (when tested for buckling) and of the head of the femur (when tested for compression) decreased appreciably immediately after spaceflights (Cosmos-782, Cosmos-936). It was also established [12] that weightlessness causes reduction of maximum moment of torsion, strain and strain function when the humerus is twisted. Rigidity of bone increases. Analogous data concerning rigidity were also obtained on the femur of rats, the limbs of which were immobilized [16].

In this regard, the question arises as to whether the above-demonstrated increase in deformability of the femur is due to the spaceflight or whether it reflects the effect of relative increase in mechanical load on the bone which was atrophied as a result of the spaceflight. Comparative analysis of effects of hypokinesia and hypodynamia offers some food for thought (Table 3).

Table 3. Mechanical characteristics of femur, tibia and humerus of animals 2.5 months old (1st, 3d and 4th groups)

Bone	Group	Parameter	Characteristics of mechan.properties				
			G^0, GPa	τ^*, MPa	γ^*	U^*, kJ/m^3	G^*, GPa
Femur	1	$\bar{x}$	4,08	40,3	0,0163	400	1,57
		$S_{\bar{x}}$	0,17	2,0	0,0010	42	0,18
	3	$\bar{x}$	3,78	29,5	0,0117	205	1,57
		$S_{\bar{x}}$	0,13	1,2	0,0006	17	0,08
	4	$\bar{x}$	3,44	39,0	0,0180	427	1,30
		$S_{\bar{x}}$	0,10	1,5	0,0011	41	0,07
Tibia	1	$\bar{x}$	6,13	48,6	0,0099	264	3,85
		$S_{\bar{x}}$	0,40	1,5	0,0006	22	0,26
	3	$\bar{x}$	6,97	50,5	0,0092	261	4,11
		$S_{\bar{x}}$	0,38	1,7	0,0006	23	0,24
	4	$\bar{x}$	6,68	54,5	0,0098	292	4,20
		$S_{\bar{x}}$	0,23	1,5	0,0003	14	0,16
Humerus	1	$\bar{x}$	4,92	48,1	0,0142	405	2,12
		$S_{\bar{x}}$	0,24	2,2	0,0007	39	0,08
	3	$\bar{x}$	4,95	32,3	0,0126	323	2,16
		$S_{\bar{x}}$	0,15	2,3	0,0009	42	0,11
	4	$\bar{x}$	5,03	52,5	0,0134	396	2,76
		$S_{\bar{x}}$	0,07	1,4	0,0005	22	0,15

It was established that, in the absence of statistically significant differences in values for modulus G^0 in animals of the 1st, 3d and 4th groups, modulus G* for the femur decreases with statistical reliability (by 17%) in animals of the 4th group and does not change in the 3d group, as compared to the vivarium control. In the bones of animals submitted to hypokinesia, we also found a tendency toward increase in maximum strain γ^* and specific

energy of strain with failure of U* (see Table 3), which could be indicative of increased resiliency of the material.

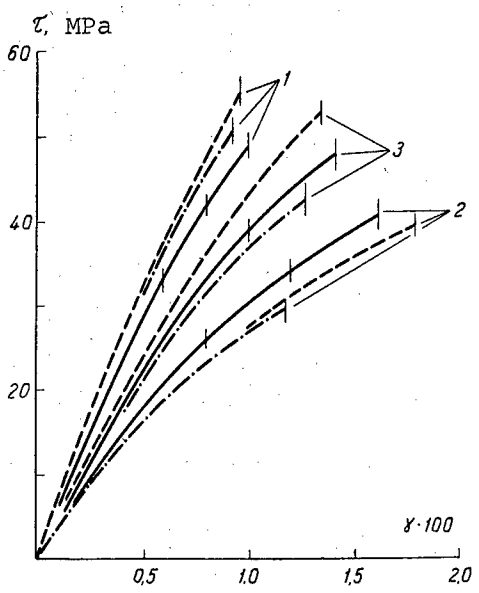


Figure 2.
Approximated mean γ-τ curves of experimental animals 2.5 months old for the tibia (1), femur (2) and humerus (3)
Solid, dash and dot-dash lines: control, hypokinetic and hypodynamic groups, respectively

At the same time, the decrease in γ* and U* demonstrated in the femur of animals in the 3d group is comparable in direction to changes in mechanical characteristics of bone immediately after spaceflights [9, 10, 12, 17], which conform to data concerning development of osteoporosis under these conditions [10, 13, 14].

As mentioned above, the type of bone is appreciably involved in determining the nature of its response to change in mechanical load, which is also illustrated in Table 3.

When submitted to torsion, the tibia demonstrates greater rigidity, which is indicated by the almost linear nature of the γ-τ function (Figure 2) and ratio of initial to failure moduli of shear: G^0/G^* equals 1.6 for the tibia and 2.5 for the femur. There is virtually no change in stress τ* under hypodynamic conditions, and it increases in the tibia under hypokinetic conditions. No appreciable changes were demonstrated in γ* and U* for the tibia between the two experimental situations.

The effects of hypokinesia are manifested in the humerus by decline of shear modulus G^0/G^* to 1.8, as compared to the control group ($G^0/G^* = 2.3$) and 9.1% increase in τ* ($P<0.04$), which could indicate that there is increase in its strength. However, we failed to detect appreciable changes in γ* and U*. At the same time, a 12% decrease in τ*, as compared to the control ($P<0.04$) was found under hypodynamic conditions, as well as a distinct tendency toward decrease in strain γ* and energy U*.

Thus, we can see (see Figure 2) that the behavior of different types of bones is not the same when tested for torsion. The tibia demonstrates maximum stability of mechanical properties, the femur--minimum and the humerus occupies an intermediate position.

We also discovered that the changes in mechanical properties of bones are a function of age. A comparison of data in Tables 3 and 4 shows that the γ-τ function presented more marked nonlinearity in the femur of control animals 6.5 months of age: here, G^0/G^* is more than 1.5 times greater than in control animals 2.5 months old. Under hypodynamic conditions, stress τ* in adult animals showed virtually no change, while strain γ* had a tendency toward

increase, whereas in young rats these parameters decreased distinctly under the same conditions. This is in good agreement with data concerning the higher sensitivity of skeletal bones of young animals to changes in mechanical load [8, 12].

Table 4. Mechanical characteristics of femur of animals at the age of 6.5 months (1st and 4th groups)

Animal group	Parameter	Characteristics of mechanical properties				
		c^0, GPa	τ^*, MPa	ν^*	U^*, kJ/m^3	c^*, GPa
1	$\bar{x}$	4,92	42,7	0,0189	543	1,21
	$S_{\bar{x}}$	0,16	2,2	0,0016	72	0,09
3	$\bar{x}$	4,47	42,8	0,0211	592	1,10
	$S_{\bar{x}}$	0,11	2,1	0,0013	61	0,06

It is difficult to comprehend the demonstrated distinctions without additional data. The following is one of the possible interpretations. It is known that a decrease in strength and rigidity of bones in the peripheral parts of the skeleton, in particular the femur, is observed immediately after space-flights [9, 10]. There is increase in sensitivity of vertebral bodies to mechanical loads. This is related to slowing of bone growth processes [12] and development of osteoporosis [13, 14]. In the recovery period after animals have flown in space (Cosmos-1129), signs of increased rate of physiological reorganization of the skeleton were discovered, in the form of faster osteo-neogenetic processes in the tibia [22] and increased incorporation of calcium in the compact bone of the femoral diaphysis [20], and these processes were supercompensatory in nature. The indicated differences could be related to both the distinctions of front and hind legs of rats due to evolution [19] and the nature of contractile properties of the corresponding muscle groups. If we consider that, with high rate of bone reorganization, some of the newly formed bone does not attain the high degree of mineralization inherent in mature bone [11], it can be assumed that the viscous component of bone, collagen fibers, play a larger part in mechanical properties of bone at the recovery stage.

BIBLIOGRAPHY

1. Biryukov, Ye. N. and Krasnykh, I. G., KOSMICHESKAYA BIOL., 1976, No 6, pp 42-46.

2. Gazenko, O. G., Grigoryev, A. I. and Natochin, Yu. V., Ibid, 1980, No 5, pp 3-10.

3. Ilin, Ye. A. and Novikov, V. Ye., Ibid, No 3, pp 79-80.

4. Knets, I. V., Pfafrod, G. O., Saulgozis, Yu. Zh. et al., MEKHANIKA POLIMEROV, 1973, No 5, pp 911-918.

5. Knets, I. V., Pfafrod, G. O. and Saulgozis, Yu. Zh., "Deformirovaniye i razrusheniye tverdykh biologicheskikh tkaney" [Deformation and Failure of Firm Biological Tissues], Riga, 1980.

6. Kregers, A. F., ALGORITMY I PROGRAMMY, 1975, No 1, p 21.

7. Pfafrod, G. O., Saulgozis, Yu. Zh., Knets, I. V. et al., MEKHANIKA POLIMEROV, 1972, No 4, pp 697-705.

8. Saulgozis, Yu. Zh., Novikov, V. Ye. and Dobelis, M. A., in "Ultrazvuk v biologii i meditsine" [Ultrasound in Biology and Medicine], Pushchino, 1981, pp 44-45.

9. Stupakov, G. P. and Korolev, V. V., in "Vliyaniye dinamicheskikh faktorov kosmicheskogo poleta na organizm zhivotnykh" [Effect of Dynamic Space-Flight Factors on Animals], Moscow, 1979, pp 174-179.

10. Stupakov, G. P., Volozhin, A. I., Zasypkin, V. V. et al., MEKHANIKA KOMPOZITNYKH MATERIALOV, 1980, No 3, pp 530-537.

11. Stupakov, G. P., Kazeykin, V. S. and Volozhin, A. I., KOSMICHESKAYA BIOL., 1983, No 3, pp 36-44.

12. Holton, E. M. and Beylink, D. J., in "Vliyaniye dinamicheskikh faktorov kosmicheskogo poleta na organizm zhivotnykh," Moscow, 1979, pp 148-157.

13. Esling, S. U., Ibid, pp 157-165.

14. Yagodovskiy, V. S., Triftanidi, L. A. and Gorokhova, G. P., KOSMICHESKAYA BIOL., 1977, No 1, pp 14-20.

15. Burstein, A. N. and Frankel, V. H., J. BIOCHEM., 1971, Vol 4, pp 155-158.

16. Jankovich, J. P. and Lange, K. O., AIAA J., 1972, Vol 10, pp 1-12.

17. Kazarian, L. E., Collins, G., Munic, L. et al., in "Gravitational Physiology," ed. J. Hideg and O. G. Gazenko, Budapest, 1980, pp 129-138.

18. Lutwak, Z., Whedon, G. D., Lachance, P. A. et al., J. CLIN. ENDOCR., 1969, Vol 29, pp 1140-1156.

19. Morrey, E. R., BIOSCIENCE, 1979, Vol 29, pp 168-172.

20. Oganov, V. S., PHYSIOLOGIST, 1981, Vol 24, No 6, Suppl, pp 55-58.

21. Rambaut, O. C. and Johnston, R. S., ACTA ASTRONAUT., 1979, Vol 6, pp 1113-1122.

22. Wronski, T. J., Morey-Holton, E. and Jee, W. S. S., PHYSIOLOGIST, 1980, Vol 23, Suppl 6, pp S79-S82.

UDC: 612.766.2-08:[612.015.31:546.41]-
06:612.015.6:577.161.22

ROLE OF VITAMIN D_3 ACTIVE METABOLITES IN REGULATION OF CALCIUM METABOLISM IN HYPOKINETIC RATS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 7 Mar 84) pp 46-50

[Article by I. N. Sergeyev, B. V. Afonin, N. V. Blazheyevich, B. V. Morukov and M. S. Belakovskiy]

[English abstract from source] The rats exposed to prolonged hypokinesia showed hypocalcemia, lower PTH and higher calcitonin concentrations in the serum, decreased calcium absorption in the small intestine, and a trend toward nephro- and arteriocalcinosis. Prophylactic administration of 24,25-hydroxy D_3, 1,25-hydroxy D_3 and their combinations enhanced calcium absorption and alleviated hypocalcemia. The changes in the hormonal regulation of calcium homeostasis can be viewed as a factor responsible for calcium metabolic disorders associated with hypokinesia.

[Text] The hormonal system that consists of parathyroid hormone (PTH), active metabolites of vitamin D_3--1,25-dihydroxycholecalciferol [$1,25(OH)_2D_3$] and 24,25-dihydroxycholecalciferol [$24,25(OH)_2D_3$]--and calcitonin (CT) maintains calcium homeostasis [15-19]. In this system, the function of $1,25(OH)_2D_3$ is aimed at immediate restoration of calcium homeostasis [9], whereas $24,25(OH)_2D_3$ probably controls calcium utilization when the body has a normal supply of this mineral, primarily in ossification processes [1, 11, 18]. Evidently, a change in ratio between formation of $1,25(OH)_2D_3$ and $24,25(OH)_2D_3$ plays an appreciable role in immediate and long-term adaptation of calcium metabolism as a function of availability of this mineral and as related to a specific functional state of the body.

We previously demonstrated that, in hypokinetic rats, there is decrease in production of $1,25(OH)_2D_3$, increase in production of $24,25(OH)_2D_3$ in the kidneys and decreased accumulation of $24,25(OH)_2D_3$ in the mucosa of the small intestine and bones [4, 17]. Such changes in metabolism of vitamin D_3 can probably be interpreted as a manifestation of adaptive changes when calcium requirements are lowered due to drastic depression of bone growth under hypokinetic conditions.

We submit here the results of determining calcium metabolism in hypokinetic rats with administration of additional amounts of active metabolites of vitamin D_3, particularly $24,25(OH)_2D_3$.

Methods

Experiments were conducted on male Wistar rats (base weight 240-280 g) kept on a diet with adequate vitamin D, containing 0.6% calcium and 0.6% phosphorus [5]. Preparations of 1α,25-dihydroxycholecalciferol and 24 R, S, 25-dihydroxycholecalciferol (Footnote 1) (The preparations were synthesized and kindly furnished to us by N. A. Bogoslovskiy, senior scientific associate at the Vitaminy Scientific Production Association), as well as a combination of both, were given daily by mouth throughout the experiment. Table 1 lists the dosage we used. The smaller of the indicated doses of each metabolite is physiological for rats [1]. The rats were kept in adjustable cages for 5 weeks.

Table 1. Effect of $1,25(OH)_2D_3$ and $24,25(OH)_2D_3$ on concentrations of Ca, Pi, PTH, CT and AP activity in blood serum of hypokinetic rats

Animal	Dosage, μg	Ca, mg/100 mℓ	Pi, mg/100 mℓ	PTH, mIU/mℓ	CT, pg/mℓ	AP activity, mU/mℓ
Control	0,1 mℓ PG	10,4±0,2	8,2±0,2	21,3±2,4	13,0±1,3	71,8±4,4
Hypokinesia	0,1 mℓ PG	9,3±0,2[а]	8,6±0,3	11,5±4,1[а]	21,4±4,2	44,8±2,7[а]
					$0,05<P_1<0,1$	
$1,25\ (OH)_2D_3$	0,03	9,9±0,1[в]	9,0±0,4	15,8±2,1	14,6±1,4	38,0±2,4[а]
			$0,05<P_1<0,1$			
$1,25\ (OH)_2D_3$	0,15	11,2±0,3[в]	10,0±0,2[в]	11,3±2,3[а]	12,6±2,2	35,6±2,8[в]
					$0,05<P_2<0,1$	
$24,25\ (OH)_2D_3$	0,25	9,6±0,2[а]	8,4±0,4	10,8±3,4[а]	12,2±2,8	44,6±2,3[а]
$24,25\ (OH)_2D_3$	1,25	10,2±0,1[б]	8,6±0,3	9,5±1,8[а]	10,6±1,4[б]	49,2±2,0[а]
$1,25\ (OH)_2D_3$ + $24,25\ (OH)_2D_3$	0,03+0,25	10,1±0,3[б]	8,5±0,4	5,2±1,5[а]	20,0±3,7	47,4±2,2[а]
$1,25\ (OH)_2D_3$ + $24,25\ (OH)_2D_3$	0,03+1,25	10,3±0,2[б]	9,0±0,4 $0,05<P_1<0,1$	5,9±1,7[а]	15,9±5,0	51,8±1,6[в]

Key for Tables 1 and 2:
superscript а) reliable difference from parameter of control animals ($P_1<0.05$)
" б) same, from parameter of hypokinetic animals ($P_2<0.05$)
" в) from parameters of both groups (P_1 and $P_2<0.05$)
PG) propylene glycol

Note: In each group we examined 8-10 animals.

We used methods escribed in [5] to measure total calcium concentration, inorganic phosphate (P_i), alkaline phosphatase (AP) activity in blood serum, as well as calcium content of the kidneys and aorta. PTH and CT concentration in blood serum was assayed by a radioimmune method using PTH-Ria (Institut National des Radioelements, Belgium) and Ria--mat hCT-II (Byk-Mallincrodt, FRG) test kits, respectively. In these kits, bovine ^{125}I-PTH (MRC 71/324) and human ^{125}I-CT, respectively, were used as standards.

Calcium transport in the small intestine was assessed by the capacity of an isolated duodenal segment to absorb ^{45}Ca by the in vitro method with noneverted

sac. We used an incubation medium [14] with total 2.5 mmol/ℓ concentration of calcium. No ^{45}Ca was added to the exogenous medium. All data are submitted in the form of arithmetic mean of indicated number of readings with standard error.

Results and Discussion

Use of $1,25(OH)_2D_3$ and $24,25(OH)_2D_3$ had no toxic effect, as assessed by change in weight of the animals (Table 2). There was no appreciable difference between weight of rats given $1,25(OH)_2D_3$ and hypokinetic animals, whereas with use of $24,25(OH)_2D_3$ or combination of $1,25(OH)_2D_3$ and $24,25(OH)_2D_3$ it was somewhat higher. At the end of the experiment, weight gain in these rats constituted 7.2-11.4%, as compared to hypokinetic animals.

Table 2. Effect of $1,25(OH)_2D_3$ and $24,25(OH)_2D_3$ on weight gain, absorption of Ca in small intestine and Ca content of kidneys and aorta in hypokinetic rats

Animal group	Dosage, μg	Weight gain, %	Ca transport, nmol·cm^{-1}·h^{-1}	Ca content, mg/g dry tissue	
				in kidneys	in aorta
Control	0,1 mℓ PG	48,7±3,7	88,6±4,6	0,88±0,06	1,89±0,14
Hypokinesia	0,1 mℓ PG	−8,7±2,8[a]	61,1±3,3[a]	1,24±0,19	2,05±0,25
				$0,05<P_1<0,1$	
$1,25(OH)_2D_3$	0,03	−4,3±3,4[a]	76,2±8,4	1,18±0,22	1,92±0,20
$1,25(OH)_2D_3$	0,15	−11,7±4,1[a]	82,1±7,1[б]	1,63±0,30[a]	2,54±0,24[a]
$24,25(OH)_2D_3$	0,25	−1,5±4,5[в]	70,2±3,8[a]	1,23±0,17	1,99±0,20
			$0,05<P_2<0,1$	$0,05<P_1<0,1$	
$24,25(OH)_2D_3$	1,25	2,7±3,1[в]	74,2±8,7	1,16±0,18	2,17±0,30
$1,25(OH)_2D_3$ + $24,25(OH)_2D_3$	0,03+0,25	1,8±4,6[a]	73,6±3,1[в]	1,11±0,16	2,10±0,30
		$0,05<P_2<0,1$			
$1,25(OH)_2D_3$ + $24,25(OH)_2D_3$	0,03+1,25	0,8±3,7[a] $0,05<P_2<0,1$	81,6±9,0 $0,05<P_2<0,1$	1,27±0,24	1,96±0,36

A normalizing effect on calcium metabolism was observed with use of the combination of $1,25(OH)_2D_3$ and $24,25(OH)_2D_3$, as well as $24,25(OH)_2D_3$ alone (see Tables 1 and 2). Blood serum Ca content and its absorption in the small intestine were close to values of control animals. AP activity in blood serum increased insignificantly. Serum PTH concentration was lower than in control animals, and it diminished, as compared to the decreased concentration of this hormone in hypokinetic rats. CT concentration did not differ reliably from levels in control animals (it was elevated in hypokinetic rats). Ca content of the kidneys and aorta did not change, as compared to its concentration in hypokinetic rats. P_i concentration increased somewhat, as compared to the control, with use of the combination of $1,25(OH)_2D_3$ and $24,25(OH)_2D_3$ in doses of 0.03 and 1.25 μg, respectively.

In a physiological dosage (0.03 μg), $1,25(OH)_2D_3$ increased serum concentrations of Ca and Pi, effectively enhanced absorption of calcium in the small intestine, decreased CT concentration and did not affect PTH concentration, serum AP activity and Ca content of kidneys and aorta.

With increase to 0.15 μg in dose of $1.25(OH)_2D_3$, we observed a tendency toward development of hypercalcemia and hyperphosphatemia (Ca and P_i concentrations reliably exceed control levels), and calcium absorption in the small intestine the most, as compared to all other groups. Serum PTH concentration did not change, while CT decreased to control levels. AP activity in serum decreased somewhat, as compared to the low activity of this enzyme in hypokinetic rats. Ca content of the kidneys and aorta increased, as compared to hypokinetic rats.

Our results indicate that in puberal but growing rats submitted to long-term rigid hypokinesia there were changes in calcium metabolism and, as we demonstrated previously [3, 5, 18], in bone: hypocalcemia, diminished absorption of calcium in the small intestine, tendency toward development of nephrocalcinosis and arterial calcinosis, drastic depression of growth and mineralization of bones of the static skeleton.

The decrease in serum PTH concentration and related inhibition of 1-hydroxylation of $25(OH)D_3$ in the kidneys could be the prime cause of diminished absorption of calcium in the small intestine, its reabsorption in the kidneys and hypocalcemia in hypokinetic rats. We cannot rule out the possibility that the decrease in PTH concentration is due to faster metabolic clearance of this hormone. The concurrent decrease in PTH concentration, AP activity in serum and production of $1,25(OH)_2D_3$ in the kidneys is apparently related to depression of remodeling of bone. Interestingly, with intensive growth of rats, the concentration of serum PTH increases [16], while AP activity [10] and production of $1,25(OH)_2D_3$ [6] decrease with age.

Intake of both metabolites and $24,25(OH)_2D_3$ alone [but not $1,25(OH)_2D_3$] lowered the concentration of PTH in hypocalcemic rats submitted to hypokinesia. The same effect of $24,25(OH)_2D_3$ and combination of $1,25(OH)_2D_3$ with $24,25(OH)_2D_3$ had been reported previously in chicks, and the combined metabolites were more effective [12].

On the basis of the obtained data and results of cited studies, it can be assumed that this is a direct effect, since it is not mediated by change in blood Ca concentration.

The increase in serum CT concentration in hypokinetic rats, which lowers the release of Ca from the labile reservoir of this mineral and inhibits bone tissue resorption [7], could lead to hypocalcemia. In addition, CT prevents absorption of calcium in the intestine [8] and increases Ca excretion in urine [13]. Perhaps, these effects of CT are attributable in part to inhibition of $1,25(OH)_2D_3$ production, which has been observed in the presence of hypercalcitoninemia. The increase in CT concentration could also be due to its slower degradation. It must be noted that CT secretion diminishes as animal growth progresses [16].

Administration of $1,25(OH)_2D_3$ and $24,25(OH)_2D_3$ lowered the concentration of serum CT in hypokinetic rats. This effect of $1,25(OH)_2D_3$ is probably attributable to its antagonistic interaction with CT [8]. Under these conditions, the effect of $24,25(OH)_2D_3$ is apparently due to the considerably normalizing action of this metabolite on bone tissue, which occurs independently of CT.

Evaluation of Ca absorption in the small intestine of hypokinetic rats given D_3 metabolites indicates that $1,25(OH)_2D_3$ is highly active in enhancing this process. This action of the metabolite in the model of Ca absorption we used is probably effected on the levels of both active and passive transport of this ion [14, 15, 20].

The effectiveness of $24,25(OH)_2D_3$ with respect to calcium absorption in the intestine of hypokinetic rats is also adequate, and it increases with increase in dosage of this metabolite. The stimulating effect of $24,25(OH)_2D_3$ on Ca absorption in the small intestine may be due to increased synthesis of $1,25(OH)_2D_3$ when this metabolite is administered, its prior 1-hydroxylation, as well as direct interaction with intestinal $1,25(OH)_2D_3$ receptors [5]. We failed to demonstrate a side-effect [unlike $1,25(OH)_2D_3$] in the form of hypercalcemia, hyperphosphatemia and calcinosis of viscera with administration of a higher dose of $24,25(OH)_2D_3$. Evidently, this is due to the fact that $24,25(OH)_2D_3$ has no marked resorptive effect on bone.

It should be noted that a tendency toward soft tissue calcinosis was observed in hypokinetic rats on a diet with optimum calcium and phosphorus content. Concentration of PTH, $1,25(OH)_2D_3$ in serum and absorption of calcium in the intestine of hypokinetic rats were diminished, while remodeling of bone tissue was slower. It is unlikely that, under such conditions, passage of calcium into extracellular fluid was constantly high. At the same time, excretion of calcium and phosphorus by the kidneys increases [2], which creates conditions for deposition of microliths in tubular lumina due to simple increase in product of Ca and P_i concentrations. Accumulation of Ca in the aorta is perhaps related to destructive changes in its wall, which has been observed in hypokinetic rats [2]. The probable immediate cause of soft tissue calcification under hypokinetic conditions is impairment of membrane transport of Ca, possible due to change in hormonal regulation of this process.

Our findings enable us to draw a tentative conclusion about the adaptive orientation of synthesis and secretion of calcium-regulating hormones in rats submitted to hypokinesia for up to 1 month. Inhibition of $1,25(OH)_2D_3$ production in the kidneys, decrease in $24,25(OH)_2D_3$ content of the small intestinal mucosa, decrease in PTH concentration and increase in CT concentration in blood cause decrease in Ca absorption in the intestine and its more intensive excretion in urine; this phenomenon is apparently indicative of a diminished need for this mineral when there is drastic slowing of bone growth under hypokinetic conditions. Thus, during hypokinesia homeostasis of Ca is maintained in accordance with the functional level of the skeleton. Preventive administration under these conditions of $1,25(OH)_2D_3$ and $24,25(OH)_2D_3$ apparently slows down development of such long-term adaptation to immobilization, enhancing calcium absorption in the intestine and causing preservation of a high enough metabolism of this mineral in bone.

BIBLIOGRAPHY

1. Alekseyeva, I. A., Spirichev, V. B., Blazheyevich, N. V. et al., VOPR. MED. KHIMII, 1982, No 5, pp 71-78.

2. Blazheyevich, N. V., Spirichev, V. B., Ushakov, A. S. et al., KOSMICHESKAYA BIOL., 1982, No 2, pp 34-40.

3. Kabitskaya, O. Ye., Savik, Z. F., Kaplanskiy, A. S. et al., Ibid, 1984, No 4, pp 49-55.

4. Sergeyev, I. N., Arkhapchev, Yu. P., Spirichev, V. B. et al., Ibid, 1983, No 2, pp 68-73.

5. Sergeyev, I. N., Blazheyevich, N. V., Spirichev, V. B. et al., VOPR. MED. KHIMII, 1982, No 5, pp 102-108.

6. Armbrecht, J. H., Zenser, T. V. and David, B. B., J. CLIN. INVEST., 1980, Vol 66, pp 1118-1124.

7. Austin, L. A. and Heath, H., NEW ENGL. J. MED., 1981, Vol 304, pp 269-278.

8. Care, A. D., Pickard, D. W. et al., in "Vitamin D: Basic Research and Its Clinical Application," eds. A. W. Norman et al., Berlin, 1979, pp 289-296.

9. DeLuca, H. F., J. AMER. DIET ASS., 1982, Vol 80, pp 231-237.

10. Duursma, S. A., van Kesteren, R. G., Visser, W. J. et al., in "Vitamin D and Problems Related to Uremic Bone Disease," eds. A. W. Norman et al., Berlin, 1975, pp 167-171.

11. Edelstein, S. and Ornoy, A., in "Vitamin D: Basic Research and Its Clinical Application," eds. A. W. Norman et al., Berlin, 1979, pp 381-389.

12. Henry, H. L., MINERAL ELECTROLYTE METAB., 1982, Vol 8, pp 179-187.

13. Knox, F. G., PHYSIOLOGIST, 1980, Vol 23, pp 1-20.

14. Martin, D. L. and DeLuca, H. F., AMER. J. PHYSIOL., 1969, Vol 216, pp 1351-1359.

15. Norman, A. W., "Vitamin D: the Calcium Homeostatic Steroid Hormone," New York, 1979.

16. Thomas, M. L. and Forte, L. R., ENDOCRINOLOGY, 1981, Vol 109, pp 1528-1532.

17. Ushakov, A. S., Spirichev, V. B., Belakovsky, M. S. et al., PHYSIOLOGIST, 1982, Vol 25, pp S45-S48.

18. Ushakov, A. S., Spirichev, V. B., Sergeev, I. N. et al., AVIAT. SPACE ENVIRONM. MED., 1984, Vol 54, pp 447-451.

19. Norman, A. W., ed., "Vitamin D: Molecular Biology and Clinical Nutrition," New York, 1980.

20. Wasserman, R. H., RED. PROC., 1981, Vol 40, pp 68-72.

UDC: 612.751.1-06:612.766.2

COMPARISON OF BONE REACTIONS OF RATS SUBMITTED TO CLINOSTATIC AND ANTIORTHOSTATIC HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 1 Jun 84) pp 50-54

[Article by V. N. Shvets, A. S. Pankova, O. Ye. Kabitskaya and Z. Ye. Vnukova]

[English abstract from source] Examination of spongy bones of rats exposed to clino- and antiorthostatic hypokinesia showed that changes in bone mass, bone cells and their precursors were similar in both cases. The bone resorption--bone formation process remained balanced. However, bone responses to clino- and antiorthostatic hypokinesia exhibited certain differences. Clinostatic hypokinesia produced greater osteoporosis in the femoral bone, whereas bone losses in the humerus, sternum and pelvis were identical. Antiorthostatic hypokinesia led to osteoporosis that was identical in every bone examined. In addition, clino- and antiorthostatic hypokinesia caused different reactions of stromal precursor cells, the latter model producing a greater effect on them. It is concluded that immobilization-induced skeletal disorders are associated with a decreased rate of bone histogenesis which proceeds at a lower level rather than with the stress-reaction.

[Text] Two experimental models are used extensively to demonstrate the distinctions of bone responses to weightlessness: clinostatic (CSH) and antiorthostatic (AOH) hypokinesia. The available data on this score indicate that exposure of man and animals to weightlessness and hypokinesia leads to similar changes in bone [3, 4, 6-8, 10, 11, 14, 16]. However, no comparative evaluation had been made of condition of bone tissue in different parts of the skeleton under CSH and AOH conditions. Our objective here was to explore this matter.

Methods

In the experiments, we used male Wistar rats 2-3 months old initially weighing 250 g. CSH was produced by putting the rats into box cages and AOH, on a special stand that enabled us to keep the animals in a tilted position, with the head down [1, 10]. They were on the usual vivarium diet. After 35 days, we removed bones of the pelvis, posterior and anterior extremities, and

sternum; bone marrow was taken from the ischial bone. The skeletal bones were fixed in a mixture of 5% formalin and Muller's fluid, decalcified in 5% nitric acid and imbedded in paraffin. Histological sections, 5-7 μm thick, were stained with hematoxylin and eosin or toluidine blue. A test grid was used for morphometry of trabecular bones. For this purpose, we used a standard ocular grid (256 squares). Intersections of square sides yields a total of 289 points spaced 0.5 mm apart. Overall area of trabeculae on the grid was estimated as percentage of total volume of metaphysis using the formula:

$$V = \frac{N}{289} \cdot 100\%,$$

where V is relative volume of trabeculae in metaphysis and N is the number of points referable to trabecular structure. Spongiosa volume was measured on longitudinal serial histological sections prepared from the distal ends of the femoral metaphysis and proximal segment of the humeral metaphysis. We examined the volume of both the entire spongiosa (primary and secondary) and primary spongiosa separately. Weight of trabeculae in the sternum and pelvic bones was determined on transverse serial sections. Width of the epiphyseal growth plate and depth of penetration of trabeculae into the cavity of long bone diaphysis were measured with an ocular micrometer. Bone cells (osteoclasts and osteoblasts) were counted over the entire region occupied by primary spongiosa at a magnification of 400×.

Stromal precursor cell content of bone marrow was examined by the cloning method after A. Ya. Fridenshteyn [5].

The adrenals were submitted to morphological examination on the 22d day of the experiment in order to study the effect of stress factors on bone. We demonstrated lipids by the luminescent microscope method of Berg and Sudan black on fresh-frozen sections of adrenal cortex. Epinephrine and norepinephrine-secreting cells of the adrenal medulla were analyzed by differentiated staining after Wood [15]. On such sections, we outlined projections of nuclei of epinephrine- and norepinephrine-secreting cells (100 nuclei of each) using an RA-6 projection attachment at 200× magnification, measured their diameter and calculated the volume of nuclei (in cubic micrometers) by conventional methods.

Results and Discussion

Humerus. The data listed in Table 1 indicate that the relative volume of the entire spongiosa and depth of its penetration into the proximal segment of the diaphysis decreased to about 2/3-1/2, of the control in experimental rats. Loss of bone mass was manifested to the same extent under both CSH and AOH conditions. As can be seen in Table 1, there was decrease to 1/3 in volume of cartilaginous tissue in the trabeculae, while the width of the epiphyseal growth plate (EGP) decreased on the average to 10/13ths of the control under both CSH and AOH. Along with the data submitted above, all this is indicative of equal inhibition of endochondral ossification in both experimental situations.

The spongiosa is unevenly distributed in the metaphysis: the region of the metaphysis situated near the EGP (primary spongiosa) has a greater profusion of trabeculae than on the periphery, i.e., closer to the diaphysis (secondary

spongiosa). In this regard, it is interesting to make a special analysis of the primary spongiosa, which is referable to the region of highest anabolic activity (this is where the following processes occur: proliferation of precursor cells and their differentiation into mature forms of bone cells, synthesis of collagen, proteoglycans and glycoproteins, and where high activity of alkaline and acid phosphatases is observed, where there is deposition of calcium salts and resorption). The results of our studies revealed that the volume of trabeculae in primary spongiosa decreases with immobilization to 5/7ths-5/9ths of the control; the amount of cartilagenous tissue in trabeculae decreases to about the same extent. As a result of adequate reduction of cartilaginous and bone tissues, the ratio between them remains on the control level, i.e., the process of endochondral ossification remains balanced. But, since the volume of primary spongiosa diminishes, we can refer to inhibition of EGP activity and corresponding decrease in appositional bone growth. In other words, endochondral ossification proceeds on a lower physiological level with immobilization. This is also confirmed by the proportionate decrease in quantity of osteoclasts and osteoblasts in primary spongiosa.

Table 1. Parameters of humerus (M±m)

Parameter	Variant of experiment		
	control	CSH	AOH
Volume of entire spongiosa, %	27,4±1,0	12,3±0,8	14,2±1.7
Volume of primary spongiosa, %	46,0±1,5	31,4±3,0	25,2±1,7
Depth of penetration of spongiosa into medullary cavity of diaphysis, mm	4,0±0,3	2,6±0,2	2,9±0,12
Cartilaginous tissue volume in entire spongiosa, %	12,0±1,0	4,0±0,5	4,0±0,6
Depth of penetration of cartilaginous trabeculae in diaphyseal medullary cavity, mm	3,4±0,2	2,2±0,2	2,0±0,2
Width of EPG, μm	200,0±4,0	144,0±6,0	168,0±6,0
Number of osteoclasts in primary spongiosa	70,8±6,0	46,0±5,0	46,0±7,8
Number of osteoblasts in primary spongiosa	400,0±24,0	235,0±16,0	224,0±30,0

Note: Here and in Tables 2 and 3, differences between the experiment and control are statistically reliable for all parameters.

Femur. On the whole the distal end of the femur was characterized by the same processes as the humerus (Table 2). The only difference from the latter is that atrophy of femoral spongiosa was more marked with CSH than AOH. In addition, there was greater decrease in trabecular volume in this bone and in number of bone cells with CSH than in the humerus, whereas the volume of cartilaginous tissue and width of EGP changed in the same proportion in both experimental variants in relation to the control. Thus, endochondral ossification is inhibited more in the femur than in the humerus, and this is particularly noticeable under hypokinetic conditions.

Sternum and pelvic bones. Table 3 shows that, regardless of experimental conditions, the volume of trabeculae in both bones diminishes to the

same extent in relation to the control. On the whole, weight loss in these bones is less marked (to about 10/13ths-1/2) than in long bones.

Table 2. Parameters of femur (M±m)

Parameter	Variant of experiment		
	control	CSH	AOH
Volume of entire spongiosa, %	25,0±2,0	8,0±0,7	16,2±1,8
Volume of primary spongiosa, %	45,8±2,0	23,8±1,3	29,0±2,0*
Depth of penetration of spongiosa into medullary cavity of diaphysis, mm	5,4±0,5	2,6±0,1	3,4±0,3*
Cartilaginous tissue volume in entire spongiosa, %	11,9±0,5	3,0±0,24	5,0±0,7*
Depth of penetration of cartilaginous trabeculae in medullary cavity of diaphysis, mm	4,14±0,28	2,16±0,15	2,62±0,14*
Volume of cartilaginous tissue in diaphysis, %	25,5±1,5	18,2±1,6	18,8±1,7
Width of EGP, μm	203,6±5,5	150,0±7,0	151,0±5,0
Number of osteoclasts in primary spongiosa	100,0±9,0	42,0±4,0	50,0±10,0
Number of osteoblasts in primary spongiosa	756,0±48,0	312,0±32,0	347,0±28,0

*Statistically reliable differences between the two experimental groups.

Table 3. Volume (%) of trabecular bone in sternum and pelvic bones (M±m)

Name of bone	Variant of experiment		
	control	CSH	AOH
Sternum	20.4±0.8	14.8±0.28	14.5±1.7
Ischial bone	13.6±0.7	8.0±0.3	9.4±1.4

Osteogenesis precursor cells. Unlike mature osteoblasts, their precursors are more sensitive to restricted motor activity. Thus, with CSH the number of such cells decreased to more than 1/3d and under AOH conditions, to about 1/7th. The data listed in Table 4 indicate that loss of spongiosa mass in the entire skeleton is attributable to slower histogenesis of bone starting on the level of precursor cells.

Adrenal. Examination of the adrenal cortex of rats submitted to AOH for 22 days revealed a normal proportion between layers, distinct zonal arrangement, with demonstrable subglomerular layer over virtually the entire length. Judging by the general structure of the cortex, its lipid content and distribution, and restoration of sudanophobic layer, one would think that the rats had adapted to some extent by this time.

Signs of hypertrophy and hyperplasia of norepinephrine-secreting cells were found in the adrenal medulla of these animals. Analysis of karyometric data revealed that there was reliable increase (in arbitrary units] in volume of norepinephrine-secreting cells (149.6±7.3, versus 115.6±4.0 in the control).

At the same time, the volume of epinephrine-secreting cell nuclei did not change (167.7±1.15 in the control and 169.4±0.6 in the experiment). The normal volume of nuclei of epinephrine-secreting cells could also be indicative of absence of stress reaction at this stage of the experiment. Activation of norepinephrine-secreting cells of the medulla is apparently a compensatory reaction, which could be instrumental in increasing peripheral vascular resistance and, consequently, maintaining vascular tonus.

Table 4. Quantity of stromal precursor cells in bone marrow (scaled to 10 explanted cells), M±m

Parameter	Variant of experiment		
	control	CSH	AOH
Total number of colonies	87.6±4.3	38.2±3.15	14.3±2.6
Number of phosphatase-positive colonies	46.3±6.0	14.0±2.7	6.9±1.2

Note: Differences between experiment and control and between the two experimental groups are statistically reliable.

Comparative analysis of parameters of spongy bone revealed that there were no basic differences in bone reactions to CSH and AOH. In both experimental variants, the changes amounted to development of systemic osteoporosis, decrease in number of bone cells and their precursors. Nevertheless, while there was a common pattern, each of the models had its own distinctions. For example, with CSH osteoporosis was more marked in the femur, while weight loss in the humerus, sternum and pelvic bones was the same. It was assumed that removal of static load on the posterior extremities in the AOH model would lead to greater development of osteoporosis in the limbs. In fact, we found that, under these conditions (unlike CSH), osteoporosis developed to the same extent in all tested skeletal bones. For the time being, it is difficult to explain the differences in responses of the femur with CSH and AOH. Perhaps, the prime factor of osteoporosis with CSH is the absence of mechanical load, whereas with AOH restriction of motor activity is probably not a deciding factor. Another difference from the models was the dissimilar reaction of stromal precursor cells. The significant decrease in number of such cells is apparently related to the effect of redistribution of blood with AOH.

The data concerning systemic involvement of the skeleton, which we have submitted here, suggest that, along with mechanical factors, there are others that lead to development of immobilization osteoporosis. In particular, some authors have shown that animals develop a stress reaction at the early stages of CSH [2]. It is known that, with administration of large doses of corticosteroid hormones, man and animals develop systemic "steroid osteopathy," the morphological signs of which have much in common with osteoporosis of diverse etiology. The foregoing warrants the assumption that stress factors may affect development of immobilization osteopathy. However, this is not confirmed for two reasons. The data pertaining to the adrenals indicate that, already by the 22d experimental day, the animals have largely adapted to experimental conditions. This is also indicated by the biochemical data in the literature of normalization of blood corticosterone in rats by the 7th day

of AOH [12]. We know that hyperadrenocorticism leads to an imbalance of processes of bone production and resorption, with prevalence of the latter [9, 13]. At the same time, the results of investigations demonstrated a balance between the two processes. This is confirmed by simple calculations, which indicate that the relative number of osteoclasts and osteoblasts per unit volume of trabecular bone in primary spongiosa did not change in the experiment, as compared to the control. This means that if the bone mass decreases by a certain value, the number of bone cells decreases proportionately to this value. Thus, by the end of the experiment, the resorption-genesis system remains balanced quantitatively. All this warrants the conclusion that even if stress factors do play a role in development of osteoporosis, they most likely do so only at the early stages of the experiment.

We believe that one of the possible mechanisms of development of immobilization osteoporosis is a decline in rate of histogenesis to a level that corresponds to the diminished volume of motor activity. In favor of this opinion are data indicative of decrease in number of bone cells and their precursors (see Tables 1, 2 and 4), as well as of diminished functional activity of osteoblasts. If, indeed, osteoporosis is based on change in bone histogenesis to a lower functional level, these structural and functional changes can apparently be assessed as an ordinary reaction reflecting the process of adaptation to restricted motor activity. How long will this process last and would it not lead to progressive deconditioning? These questions remain open for the time being.

BIBLIOGRAPHY

1. Ilin, Ye. A. and Novikov, V. Ye., KOSM. BIOL., 1980, No 3, pp 79-80.
2. Portugalov, V. V., Gazenko, O. G., Ilina-Kakuyeva, Ye. I. et al., Ibid, 1967, No 6, pp 18-25.
3. Rokhlin, G. D. and Levites, E. P., Ibid, 1975, No 1, pp 20-22.
4. Stupakov, G. P., Volozhin, A. I. and Didenko, I. Ye., BYUL. EKSPER. BIOL., 1981, No 5, pp 544-546.
5. Fridenshteyn, A. Ya. and Luriya, Ye. A., "Kletochnyye osnovy krovetvornogo mikrookruzheniya" [Cellular Bases of the Hematopoietic Microenvironment], Moscow, 1980.
6. Esling, S. U., in "Vliyaniye dinamicheskikh faktorov kosmicheskogo poleta na organizm zhivotnykh" [Effect of Dynamic Spaceflight Factors on Animals], Moscow, 1979, pp 157-165.
7. Yagodovskiy, V. S. and Gorokhova, G. P., Ibid, pp 165-174.
8. Yagodovskiy, V. S., Triftanidi, L. A. and Gorokhova, G. P., KOSM. BIOL., 1977, No 1, pp 14-20.
9. Jowsey, J., "Metabolic Disease of Bone," London, 1977.
10. Morey, E. R., BIO-SCIENCE, 1979, Vol 29, pp 168-172.

11. Peck, W. A., Kohler, G. and Rifas, L., in "Osteoporosis. Recent Advances in Pathogenesis and Treatment," eds. H. F. DeLuca et al., Baltimore, 1981, pp 67-76.

12. Popovic, V., Popovic, P. and Honeycutt, C., PHYSIOLOGIST, 1982, Vol 25, pp 77-78.

13. Raman, A., QUART. J. EXP. PHYSIOL., 1969, Vol 54, pp 11-15.

14. Vogel, J. D. and Whittle, M. W., AMER. J. ROENTGENOL., 1976, Vol 126, pp 1296-1297.

15. Wood, J. G., AMER. J. ANAT., 1963, Vol 112, pp 72-73.

16. Wronski, T. J., Morey, E. R. and Jee, W. S., PHYSIOLOGIST, 1980, Vol 23, pp 79-82.

UDC: 629.78:612.44.014.2

CONDITION OF THYROID GLAND AND C CELLS DURING LONG-TERM ROTATION (MORPHOLOGICAL AND BIOCHEMICAL INVESTIGATION)

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 19 Dec 84) pp 54-57

[Article by G. I. Plakhuta-Plakutina, Ye. A. Savina and B. V. Afonin]

[English abstract from text] The thyroid and parathyroid glands of 65 Wistar rats centrifuged for 30 days at 1.1 and 2.0 G were examined histologically and biochemically. The centrifugation led to a higher activity to C cells, an increased rate of thyro-calcitonin (TCT) synthesis and excretion, i.e., C-cell degranulation, and a significant (two-fold) increase of TCT in plasma. The stimulation effect of the TCT-producing system persisted during 7-postrotation days and was very distinct in the animals exposed to 2.0 G. There were no morphological changes in the parathyroid glands or in the PTH concentration in the plasma.

[Text] The biological effects of artificial gravity on animals and man are directly related to investigation of the mechanisms of action of weightlessness. Experiments on biosatellites revealed that 18-22-day exposure to weightlessness consistently leads to depression of functional activity of thyroid C cells, which synthesize calcitonin, a hormone that is involved in control of calcium metabolism.

For this reason, it was interesting to investigate the effect of hypergravity on the structure and function of C cells during prolonged rotation of animals on a centrifuge, as well as on calcitonin (CT) and parathyroid hormone (PTH) content of blood plasma, since these systems are directly involved in hormonal regulation of different types of metabolism and particularly calcium metabolism.

Methods

The thyroids from 65 Wistar rats, which were decapitated within the first 4 h and 2 and 7 days after 30-day rotation on a centrifuge, served as material for histological examination. The experimental material was taken from animals kept in peripheral containers on the centrifuge (group P--2G), in central containers (group C--1.1 G) and in the vivarium (control--K).

There were 7 animals in each group. The experimental conditions were described previously [1]. The thyroids were weighed on a torsion balance, fixed in Bouin liquid and imbedded in paraffin. Sections were stained with hematoxylin and eosin. Colloid was stained by the method of Marais, which made it possible to differentiate between follicles containing iodinated thyroglobulins (light blue colloid) and without them (yellow colloid) [6]. We used Helmy's stain for demonstration of C cells and evaluation of their functional state, and silver nitrate impregnation by the method of de Grandi [5].

Blood (plasma) collected after decapitating the animals served as material for biochemical studies. The concentrations of PTH and CT were determined by a radioimmune method using kits of the CIS (France) and IRE (Belgium) firms.

Results and Discussion

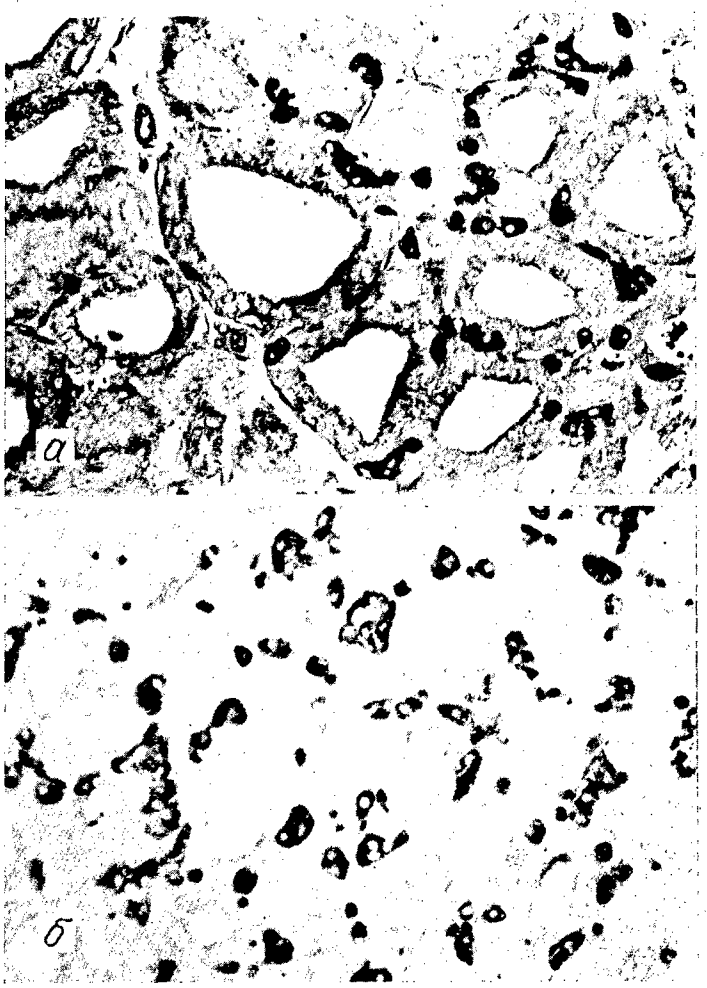
Upon termination of 3-day rotation at gravity levels of 1.1 and 2.0 G (1-4 h after stopping the centrifuge), relative and absolute weight of the thyroid did not differ appreciably from the control at all tested times. Histological examination of the thyroid revealed morphological signs of intensification of functional activity. There was prevalence of follicles of medium and small size lined with taller cuboidal and columnar epithelium than in the control, with protrusion of apical zones into the lumen of the colloid. The colloid presented signs of increased resorption in the form of marginal and central vacuolization. Staining by the method of Marais yielded light blue follicles in 90-100% of the cases and yellow, in 5-10%, which is above control levels (70-80% of the follicles in sections contained light blue colloid and the rest, yellow). Such tinctorial properties of colloid are indicative of high iodinated thyroglobulin content in the thyroid of experimental groups of animals. There was quite marked plethora of the capillary network. We failed to demonstrate appreciable differences between group P and C rats with respect to condition of the parenchyma.

Both experimental groups of rats distinctly demonstrated an increase in number of C cells. They formed "nests" of 6-10 cells more often than in the control. There was prevalence in the population of lightly stained parafollicular cells with large nucleus and loosely arranged secretory granules in the cytoplasm (see Figure). In group P, there was prevalence of a process of activation of hormone synthesis and its release, because of which optically clear (degranulated) cells with vague outlines were demonstrable. In the C group, the signs of degranulation were less marked; along with cells without granules, we encountered groups with deposited secretions.

Biochemical analysis of blood plasma showed elevated concentrations of CT in both experimental groups, exceeding the control by more than 2 times (see Table).

On the 2d postrotation day, the histological structure in experimental animals was characterized by consolidation of colloid, appearance of early dystrophic changes in the form of desquamation of cells and swelling of basal membranes. The population of C cells remained quite large, and the cells presented different stages of the secretory cycle. In addition to retention of signs of degranulation, we observed early phases of accumulation of fine secretory

granules. By the 7th day, there were more cells at the phase of accumulation of secretory granules, with persisting variability of functional state.



State of thyroid C cells during prolonged rotation. Microphotograph. De Grandi method of impregnation with silver

а) control; eyepiece 7×, lens 16×

б) increase in population of C cells with 30-day rotation on centrifuge; eyepiece 7×, lens 16×

On the 2d day of the aftereffect period, elevated CT concentration persisted in both experimental groups, but it was not reliable in comparison to the control. On the 7th day of recovery, a rise in CT concentration in blood was demonstrated only in P group animals. Evidently, there is hormonal reorganization of the CT system in response to diminished gravity in this group of animals after 30-day rotation, with significant release of CT secretion into blood.

No morphological changes were demonstrable at any stage of the aftereffect period in parathyroid glands on the light-optic level. A comparison of

PTH and CT concentrations in plasma with 30-day rotation (M±m)

Time of exam.	Group	PG, ng/mℓ	CT, ng/mℓ
0 day of rotation (1-4 h)	K	3,77±0,27	15,0±3,0
	C	3,27±0,25	32,1±3,9*
	P	3,15±0,25	42,4±9,0*
2d day of aftereffect period	K	4,15±0,37	17,6±3,0
	C	5,34±0,47	32,3±6,8
	P	4,20±0,26	27,1±8,0
7th day of aftereffect period	K	5,26±0,59	17,6±2,1
	C	6,12±0,56	24,0±3,3
	P	4,53±0,29	36,4±6,6*

* $P<0,05$

plasma PTH content in experimental and concurrently decapitated control animals (at each tested time) failed to demonstrate reliable differences.

Thus, the results of this investigation revealed that rotation of animals on a centrifuge elicits an increase in function of both the parenchyma of the thyroid and C-cell system, regardless of location in relation to axis of rotation (groups P and C). The morphological signs of activation of C cells, particularly after the centrifuge was stopped, are consistent with the increase in blood CT content. Consequently, both rotation itself (group C) and, particularly, hypergravity (group P) have a stimulating effect on CT production and function of the thyroid as a whole. This effect is relatively persistent, since signs of CT hyperproduction are still present in the recovery period, and they are the most marked in group P.

The absence of morphological manifestations of parathyroid response in experimental animals and the wide fluctuations of PTH levels in control and experimental groups of animals did not enable us to draw definite conclusions as to the effect of rotation and hypergravity on parathyroid function.

In the comparative aspect, the results of examining the thyroid of animals submitted to weightlessness (for 18-22 days) are interesting. As was shown previously [2], weightlessness leads to decrease in number, reduction in size of C cells and volume of their nuclei, which is a reflection of their functional depression, and C cells react very distinctly to the animals' return to earth's gravity. With increase in time after return to earth (after 9-13 h and, particularly, 2 days), C cells presented distinct signs of increased functional activity [3]. Onboard use of artificial gravity equaling the level on earth aboard Cosmos-936 biosatellite also had a stimulating effect on function of C cells and thus prevented development of the adverse effects of weightlessness [4].

The morphological and biochemical evaluation made here of the calcitonin-producing system convinced us that, in contrast to weightlessness, both rotation itself and, particularly, increased gravity generated by accelerations have a stimulating effect on this level of hormonal regulation of calcium metabolism. The findings indicate that there is a need to conduct investigations to determine the optimum parameters of artificial gravity that prevents impairment of this type of metabolism in weightlessness.

BIBLIOGRAPHY

1. Kotovskaya, A. R., Krasnov, I. B. and Shipov, A. A., KOSMICHESKAYA BIOL., 1985, No 4, pp 53-57.

2. Plakhuta-Plakutina, G. I., ARKH. ANAT., 1979, No 3, pp 17-22.

3. Idem, KOSMICHESKAYA BIOL., 1979, No 3, pp 80-84.

4. Idem, Ibid, 1980, No 3, pp 29-33.

5. De Grandi, P., VIRCHOWS ARCH. ABT. B. ZELL-PATH., 1970, Vol 6, pp 137-150.

6. Des Marais, A. and La Ham, O. N., CANAD. J. BIOCHEM., 1962, Vol 40, pp 227-236.

UDC: 616-001.12-036.11-07:616.1-008.1

CONDITION OF CARDIOVASCULAR SYSTEM IN PRESENCE OF ACUTE MOUNTAIN SICKNESS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 6 Nov 84) pp 57-62

[Article by M. M. Mirrakhimov, R. O. Khamzamulin and V. A. Larkov]

[English abstract from source] Fifteen subjects with uneventful adaptation and 28 subjects with acute high mountain sickness were kept at an altitude of 3600 m. Prior to the exposure all the test subjects, aged 18-20, were essentially healthy. As compared to the controls, the subjects with acute high mountain sickness showed a greater increment in heart rate, blood pressure in the brachial artery, pulmonary hypertension and vasoconstriction. It was found that the subjects susceptible to acute high mountain sickness exhibited (at sea level) higher values of heart rate and R wave in the ECG II lead and lower systolic pressure in the brachial artery. These findings can serve as predictors of acute high mountain sickness.

[Text] Acute mountain sickness (AMS) is the most frequent form of human altitude deadaptation observed during brief stays at altitudes of 2.5-3 km or more above sea level [4]. To date, studies have been made of the incidence of AMS [12, 15], its clinical manifestations [1, 5, 13], and guidelines offered for treatment [11, 16, 17] and prevention [6, 10]. At the same time, the functional state of different systems of the body in the presence of AMS have been little-studied, while diagnosis of this deadaptation syndrome does not have precise quantitative criteria, and is usually based on the subjective sensations of patients. Our objective here was to investigate some of the functional parameters of the cardiovascular system in patients with AMS.

Methods

We conducted a clinical and functional observation of 30-day adaptation of 43 essentially healthy men 18-20 years of age to an altitude of 3600 m above sea level (Murgab village, East Pamirs). The subjects were divided into two groups, according to nature of adaptation to high altitude: the 1st group consisted of 15 men with uneventful course of adaptation (control group), and the 2d, of 28 men who developed mild (23 cases) or moderate (5 cases) forms of AMS within the first 3 days at the indicated altitude. The diagnosis of

AMS was made on the basis of typical clinical symptoms (headache, vertigo, sleep disorder, anorexia, marked dyspnea, cyanosis, etc.), which persisted for more than 3-5 days.

The functional examination included recording of heart rhythm and measurement of arterial pressure (BP) in the brachial artery by conventional auscultative methods, indirect measurement of pulmonary systolic BP (PSBP) using the Burstin nomogram on the basis of synchronous recording of ECG, [phonocardiogram] and cardiogram of the right ventricle [9], recording rheopulmonograms (RPG) of the right lung by the method of Yu. T. Pushkar [8] and atrial ECG in the conventional standard and unipolar leads (recording rate 100 mm/s, amplification 1 mV = 2 cm).

The subjects were examined before the ascent in the village of Gulcha (1650 m above sea level), then on the 5th, 10th and 30th day of adaptation. We used a Mingograph-34 4-channel polygraph of the Siemens firm and a 4RG-01 4-channel rheograph (recording in the frequency band of 0-500 Hz, calibration signal 0.1 Ω).

The material was processed by the method of variational statistics with use of Student's criterion.

Results and Discussion

Our results indicated that functional parameters of the cardiovascular system of healthy subjects and those with AMS underwent marked dynamics under the influence of the mountain climate. Thus, we demonstrated in subjects of the 1st group, on the 5th day of adaptation, a reliable increase in heart rate, which gradually leveled off by the end of 1 month's stay at high altitude (Table 1). Comparable changes were found in the 2d group of subjects. However, unlike the control, with AMS there was more marked increase in heart rate at the early stage of adaptation and it persisted at subsequently tested times.

Measurement of BP in the brachial artery also revealed typical changes in its parameters with ascent in AMS subjects. As can be seen in Table 1, this parameter did not undergo appreciable change in the control group, whereas in AMS cases, we demonstrated on the 5th day of adaptation a noticeable rise in both systolic and diastolic BP, which persisted to the end of the observation period at high altitude. We were impressed by the fact that systolic BP was lower and heart rate higher prior to the ascent in subjects who subsequently developed AMS than in those whose adaptation to high altitude was good.

We observed some distinctions when we compared dynamics of PSBP. In healthy subjects, there was reliable increase in this parameter, from 31.04±0.85 to 35.62±1.91 mm Hg, on the 5th day of adaptation. Later on (30th day of observation) PSBP level reverted to baseline values, thereby confirming the thesis that healthy subjects developed moderate pulmonary hypertension at altitudes in excess of 2.5 km above sea level, manifested the most at the early stage of individual adaptation [3, 6]. In contrast, increment of PSBP in AMS subjects on the 5th day of adaptation was more significant, and it remained at a reliably high level on the 30th day.

Table 1. Dynamics of some hemodynamic parameters in 1st and 2d groups of subjects during 30-day adaptation to high altitude (M±m)

Group	Heart rate, per min				Systolic BP, mm Hg			Diastolic BP, mm Hg			PSBP, mm Hg			
	baseline	day of adaptation			baseline	day of adaptation		baseline	day of adapt.		baseline	day of adaptation		
		5	10	30		5	10		5	10		5	10	30
1	61,91±2,19	70,36±1,99*	—	68,0±3,47	115,33±1,91	112,66±2,38	118,33±2,47	68,33±2,21	71,66±1,66	72,33±1,45	31,01±0,85	35,62±1,91*	—	30,11±0,41
2	70,38±2,43	84,85±2,07*	74,86±2,33	76,95±2,22*	108,79±1,71	121,66±2,44*	117,67±2,09*	68,82±1,83	80,0±1,97*	76,07±1,69*	32,0±0,66	40,2±2,30*	35,0±1,65	35,5±1,52*

*Here and in Tables 2 and 3, reliable changes in parameters; a dash indicates there are no data.

Table 2. Dynamics of RPG parameters in 1st and 2d groups of subjects during altitude adaptation (M±m)

Group	a—a				$\frac{ab}{RR}$				$\frac{bc}{RR}$				$\frac{ac}{RR}$			
	BL	DA			BL	DA			BL	DA			BL	DA		
		5	10	30		5	10	30		5	10	30		5	10	30
1	0,15±0,007	0,15±0,010	—	0,16±0,007	0,075±0,005	0,063±0,005	—	0,081±0,008	0,13±0,013	0,126±0,014	—	0,135±0,014	0,219±0,017	0,191±0,017	—	0,219±0,017
2	0,13±0,004	0,16±0,005*	0,15±0,009	0,15±0,006*	0,064±0,005	0,072±0,006	0,067±0,010	0,090±0,006*	0,126±0,010	0,133±0,020	0,137±0,020	0,135±0,008	0,196±0,013	0,208±0,015	0,207±0,025	0,228±0,012*

Group	RI				AFP				V_{max}				$\bar{V}_{sl}$			
	BL	DA			BL	DA			BL	DA			BL	DA		
		5	10	30		5	10	30		5	10	30		5	10	30
1	2,07±0,22	1,59±0,18	—	1,32±0,14*	2,31±0,22	1,71±0,19	—	1,58±0,19*	1,91±0,18	1,58±0,19	—	1,85±0,26	0,62±0,06	0,46±0,04	—	0,41±0,06*
2	2,24±0,20	1,34±0,16*	1,62±0,29	1,64±0,13*	2,46±0,22	1,63±0,17*	1,53±0,43	1,77±0,15*	2,12±0,24	1,04±0,13*	1,07±0,23*	0,99±0,09*	0,76±0,10	0,39±0,04*	0,39±0,06*	0,42±0,04*

Key: BL) baseline DA) day of adaptation

The demonstrated PSBP changes were associated with typical dynamics of RPG parameters (Table 2). During the stay at high altitude, healthy subjects showed reduction of mean rate of slow blood delivery (V_{sl}) which was reliable on the 30th day of adaptation. This is indicative of constriction of small resistive vessels in the pulmonary circulation, which is apparently the basis of elevation of pulmonary BP [3]. Concurrently, the same group of subjects presented diminished delivery of blood and blood flow per second in pulmonary tissue (negative dynamics of rheographic index--RI--and amplitude-frequency parameter--AFP), which became statistically significant by the 30th day at high altitude. In addition, at high altitude the healthy subjects presented some decrease in contractility of the right ventricular myocardium, as indicated by a tendency toward decline of maximum velocity of rapid delivery of blood (V_{max}) on the RPG.

There were similar changes in RPG parameters in the 2d group of subjects after ascent to high altitude; however, they were appreciably more marked than in the control. Thus, while a significant decline of $V_{m.sl}$ was observed in the 1st group of subjects only on the 30th day, in the 2d group marked reduction of this parameter was demonstrated throughout the month in the mountains. Likewise, the decrease in delivery of blood (RI), blood flow per second (AFP) in pulmonary vessels and contractility of the right ventricular myocardium (V_{max}) was more marked and persistent. Furthermore, the 2d group of subjects presented a reliable extension of periods of rapid and maximum delivery of blood to the lungs (according to RPG), which was indicative of increased resistance to blood flow on the part of resistive pulmonary vessels. On the whole, these distinctions of RPG parameters indicate that hypoxic vasoconstriction in the pulmonary circulation, diminished contractility of the right ventricle and related reduction in delivery of blood to pulmonary vessels were more marked in AMS cases than in healthy subjects.

Such dynamics of RPG are consistent with the greater PSBP increment observed in the 2d group of subjects and explains why there is more marked pulmonary hypertension with AMS. Evidently, the demonstrated distinction is related to hyperreactivity of the vascular bed in the pulmonary circulation and a tendency toward its excessive vasoconstriction in response to the hypoxic stimulus in the presence of AMS. Extension of Q-a period on the RPG, which was demonstrated in the 2d group and is related apparently to increased duration of tension period for the corresponding ventricle, is also indicative of greater decline of right ventricular contractility in such patients. As we know from the physiological bases of rheography, the ventricular tension phase along with time of propagation of rheographic wave from the heart to the site of electrode application is one of the values that make up the Q-a period on rheograms [8]. On the other hand, it was learned that the early stage of altitude adaptation of man is characterized by an increase in tension period of the right ventricle [6].

As for the atrial ECG, an increase in amplitude of P wave in the second standard lead was recorded in both groups of subjects after their arrival at high altitude, which was reliable on the 5th day of adaptation and occurred in the presence of insignificant changes in the other parameters of analyzed curves (Table 3). These findings conform to existing conceptions of development of an acute overload on the myocardium of the right heart even with a

Table 3. Dynamics of atrial ECG parameters in 1st and 2d groups of subjects during 30-day adaptation to high altitude (M±m)

Group	(Makruz) index				Duration of P wave				Amplitude of P wave in lead II				Time of internal right atrial deflection			
		day of adaptation				day of adaptation				day of adaptation				day of adaptation		
	BL	5	10	30	BL	5	10	30	BL	5	10	30	BL	5	10	30
1	1,71±0,088	1,64±0,069	—	1,73±0,097	0,090±0,004	0,094±0,003	—	0,10±0,027	0,95±0,099	1,23±0,084*	—	1,05±0,097	0,046±0,002	0,041±0,002	—	0,046±0,002
2	1,54±0,062	1,50±0,069	1,58±0,133	1,54±0,065	0,094±0,002	0,092±0,003	0,085±0,005	0,093±0,002	1,81±0,074	2,26±0,047*	2,05±0,066	1,94±0,082	0,052±0,006	0,058±0,012	0,039±0,003	0,044±0,001

Key: BL) baseline

brief stay at high altitudes, which is manifested, in particular, by appropriate ECG changes [12]. At the same time, we were impressed by the appreciable difference between the compared groups in base amplitude of P wave. The relatively high mean value for this parameter in the background examination of AMS cases which, it is true, did not exceed standard values [7], can be interpreted as the possible result of hyperreactivity of the vascular bed in the pulmonary circulation, which was manifested rather distinctly at high altitude.

This distinction in the reaction of the pulmonary circulatory system could lead to inadequate increase in pulmonary vascular resistance, blood pressure in the system of pulmonary circulation and, consequently, a postload on the right heart exposed to perturbing factors already at moderate altitudes, where the baseline studies were conducted.

Thus, the results of our investigation revealed that the response of the cardiovascular system to high-altitude climate is more marked in subjects with AMS than in the case of favorable course of brief adaptation to high altitude. In particular, this is manifested by greater increment of heart rate, systemic and pulmonary BP, vasoconstriction and decreased delivery of blood to pulmonary vessels. On the other hand, in subjects suffering from AMS, before the ascent we demonstrated a faster heart rate, relatively low systolic BP in the brachial artery and higher amplitude of P wave on the ECG. This distinction of their base state opens up some prospects, in the sense of detecting people with a predisposition to AMS. Previously, one of the authors of this report proposed, in a discussion of the question of base status (before ascent in the mountains) of the body and its baseline resistance, that several functional levels be distinguished for physiological systems: base, which is demonstrable under conditions of basal metabolism,

working, which is related to performance of ordinary loads and exposure to customary, stereotypic stimuli, and maximum, which is limited to the reserve capacities of the body [2]. On this basis, we could assume that the body's adaptability would increase as a result of purposeful conditioning, due to reduction of baseline functional level of physiological systems at rest and elevation of its maximum level.

The hypothesis that there is narrowing of adaptive capacities of the body with elevation of base level of cardiovascular system function is confirmed by the relatively high base values for heart rate and amplitude of atrial ECG complex in subjects with predisposition to AMS. At the same time, one cannot interpret all low base levels of physiological functions as a positive sign and evidence of a wide range of adaptability of the body. A tendency toward low base BP levels in the 2d group of subjects indicates that there are top and bottom limits to the optimum base functional level of the cardiovascular system under basal metabolic conditions and at rest. However, determination of quantitative criteria of these limits, as well as development of scientifically validated guidelines for long-term prediction of altitude adaptation of man and his cardiovascular system, are the subject of future investigations.

BIBLIOGRAPHY

1. Mashkovskiy, V. G., in "Syezd terapevtov Tadzhikistana. 2-y. Materialy" [Proceedings of 2d Congress of Tajik Internists], Dushanbe, 1980, pp 78-79.

2. Mirrakhimov, M. M., FIZIOLOGIYA CHELOVEKA, 1975, No 6, pp 1018-1026.

3. Mirrakhimov, M. M., Khamzamulin, R. O. and Murataliyev, T. M., Ibid, 1978, No 3, pp 469-474.

4. Mirrakhimov, M. M. and Goldberg, P. N., "Gornaya meditsina" [Mountain Medicine], Frunze, 1978.

5. Idem, "Vysokogornaya dizadaptatsiya cheloveka" [High-Altitude Human Deadaptation], Moscow, 1981.

6. Muratalieyv, T., "Effect of Altitude Hypoxia on Contractility of Right and Left Ventricles of the Heart of Healthy Individuals and Those Suffering From Bronchial Asthma], candidatorial dissertation, Frunze, 1979.

7. Orlov, V. N., "Rukovodstvo po elektrokardiografii" [Manual of Electrocardiography], Moscow, 1983.

8. Pushkar, Yu. T., in "Vsesoyuznyy syezd terapevtov. 15-y. Trudy" [Transactions of 15th All-Union Congress of Internists], Moscow, 1964, pp 274-278.

9. Burstin, L., BRIT. HEART J., 1967, Vol 29, pp 396-404.

10. Currie, T. T., Carter, P. H. and Champion, W. L., MED. J. AUST., 1976, Vol 2, pp 168-170.

11. Gray, C. W., Bryan, A. C., Frayser, R. et al., AEROSPACE MED., 1971, Vol 42, pp 81-84.

12. Hackett, P. H., Rennie, D. and Levine, H. D., LANCET, 1976, Vol 2, pp 1149-1155.

13. Houston, C. S. and Dickinson, J., Ibid, 1975, Vol 2, p 758.

14. Oswald, O., in "High Altitude Physiology and Medicine," New York, 1982, pp 298-300.

15. Sutton, J. and Lasarus, L., MED. J. AUST., 1973, Vol 1, pp 345-346.

16. Ward, M., "Mountain Medicine," Toronto, 1981.

17. Wilson, R., ANN. INTERN. MED., 1973, Vol 78, pp 421-428.

UDC: 612.82.014.423-08

RAT BRAIN IMPEDANCE IN STATIONARY MAGNETIC FIELD

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 22 Aug 84) pp 62-64

[Article by L. D. Klimovskaya, N. P. Smirnova and A. S. Dyakonov]

[English abstract from source] The cortical impedance of the large hemispheres of nembutal-anesthetized rats exposed to a constant magnetic field of 0.1, 0.4 and 1.6 T was investigated. During 20 min. exposure the impedance decreased (at the expense of a decrease in both of its components--capacity and active resistance). The impedance decrease was more pronounced (up to 93%) and statistically significant in a field of 1.6 T. After exposure the impedance decrease persisted for 10 min.

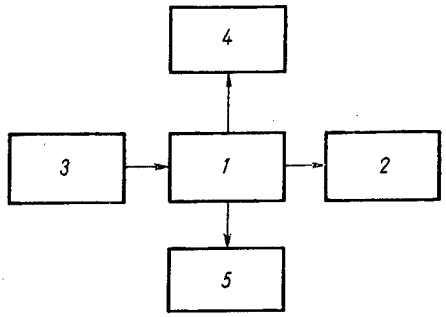
[Text] It was previously demonstrated in experiments on rabbits and rats [6] that generalized changes occur in bioelectric processes in the brain during exposure to high-intensity stationary magnetic fields (SMF). The changes in spontaneous bioelectric activity were manifested by appearance of synchronized, high-amplitude rhythms in different parts of the brain. Frequency and amplitude analysis revealed an increase in general voltage of brain electrograms with a shift of the frequency spectrum in the direction of higher frequencies due to intensification of α and β waves. The changes in evoked bioelectric activity consisted of increase in amplitude of potential with complication of its shape due to appearance of extra waves [4]. The nature of the bioelectric changes warrants the assumption that they are based on changes in physical properties of brain tissue. Data concerning the direct effect of SMF on the brain, which were obtained in experiments on a neuronally isolated strip of the cerebral cortex [8], are indicative of the significance of changes in properties of brain tissue to development of bioelectric reactions. There are conceptions to the effect that there is a link between nature of bioelectric activity of the brain and impedance level. Thus, it was shown that, with decline of cerebrocortical impedance elicited by shunting with a silver plate, there is increase in amplitude of evoked potentials [9]. Concurrent change in bioelectric activity and impedance was observed in the presence of different functional states of the brain: administration of anesthetics, hypothermia, formation of an epileptiform focus by local application of strychnine [2, 5, 1].

There is only one indication in the literature of decreased impedance of the rabbit brain with exposure to an SMF of 200 Oe (0.02 T) [3].

Our objective here was to measure impedance of the rat brain with exposure to SMF with 0.1, 0.4 and 1.6 T induction.

Methods

Experiments were performed on 24 white rats under nembutal anesthesia (40 mg/kg, intraperitoneally). We used bipolar silver electrodes, 200 μm in diameter, to measure impedance; they were implanted in the cerebral cortex at a distance of 1-2 mm from one another. Measurement of electric resistance of brain tissue was made by the compensation method using an alternating current bridge, for which purpose we assembled a device, the block diagram of which is illustrated in the Figure. We took readings at a frequency of 10 kHz. Voltage in the measuring diagonal of the bridge, which was monitored with a voltmeter, did not exceed 50 mV.



Block diagram of experimental unit
1) alternating current bridge R571M
2) null indicator F582
3) generator F578
4) microvoltmeter VZ-40
5) object

In the experiment, we measured capacitance (C) and tangential angle of dielectric losses (tg δ), which is unambiguously determined by the magnitude of active resistance of the cerebral cortex (R), at a fixed frequency (f). The components of combined resistance and impedance were calculated using the following formulas for the capacitance component of combined resistance:

$$X_C = \frac{1}{2\pi f c},$$

active resistance:

$$R = \frac{\text{tg } \delta}{2\pi f C},$$

and total resistance of tissue, i.e., impedance:

$$Z = \sqrt{R^2 + X_C^2}$$

The studies started 30 min after implantation of electrodes. We measured baseline values for electric resistance of the brain 2-3 times in 20 min. The animals were then submitted to total body vertical SMF with 0.4 T induction on an SP15A electromagnet, or 0.1 and 1.6 T on an SP57A electromagnet. The detailed specifications for the electromagnetics are given in previously published works [6, 7]. In the tests with the SP15A electromagnet, resistance was measured immediately after exposure to SMF of 0.4 T, after 10 and 20 min of exposure, as well as immediately after and 10 min after turning the magnet off. Experiments with induction of 1.6 T were conducted following the same protocol, with the exception of an additional reading with 0.1 T induction--residual magnetism in the gap of the SP57A electromagnet.

Results and Discussion

Exposure to SMF did not lead to substantial changes in electric resistance of the brain. During exposure of animals to the magnetic field, we observed an insignificant and gradual decline of brain impedance referable to both components--capacitive and active resistance. Decline of impedance persisted for 20 min after discontinuing exposure due to active resistance. The measurements are listed in Tables 1 and 2.

Table 1. Impedance of rat cerebral cortex with exposure to 0.4 T SMF

Base value, kΩ (n=13)	Changes, %				
	in SMF			after SMF	
	immediately	10 min later	20 min later	immediat.	10 min later
3,19±0,67	100,60±2,12	98,86±2,41	96,38±1,57*	99,71±2,95	97,18±2,65
10,89±1,80	99,96±0,48	98,41±1,02	97,96±1,17	98,00±1,16	96,30±1,77*
11,36±1,91	100,07±0,57	98,69±1,22	97,85±1,13	98,09±1,17	96,75±1,45*

* $P<0,05$

Table 2. Impedance of rat cerebral cortex with exposure to 0.1 and 1.6 T SMF

Base value, kΩ (n=11)	Changes, %					
	0.1 T,	1.6 T			after SMF	
	immediat.	immed.	10 min later	20 min later	immed.	10 min later
4,61±0,84	95,59±1,35	94,83±1,31*	92,45±2,61*	92,74±3,78	93,93±3,90	94,10±4,64
12,61±1,97	98,36±1,56	97,17±1,32*	94,05±1,80*	92,99±2,04*	92,47±2,82*	91,54±3,39*
13,29±2,13	98,09±1,54	96,92±1,33*	93,40±1,81*	92,92±2,82*	92,54±2,95*	91,15±3,53*

* $P<0,05$.

As can be seen in Tables 1 and 2, the decline of impedance was more marked (to 93%) and reached statistically reliable values with exposure to 1.6 T SMF.

A comparison of changes in cerebral cortex impedance to changes in bioelectric activity during exposure to SMF revealed inconsistency between dose and time characteristics of these effects. Significant changes in impedance were demonstrable only with 1.6 T induction, they developed gradually and there was no recovery for 10 min after exposure. Changes in both spontaneous and evoked bioelectric activity of the brain occurred immediately after placing animals in magnetic fields of rather high induction; they persisted without particular fluctuations over the entire exposure period and rapidly disappeared after turning the electromagnet off. Reliable changes in evoked potentials of the cerebral cortex were observed at considerably lower induction--in SMF of 0.2 T [4]--and in spontaneous activity--in SMF of 0.3 T [6].

Thus, the dramatic intensification of bioelectric activity of the brain, which occurred in animals during exposure to SMF, can apparently not be

attributed to increased electric conduction of brain tissue. Most probably, it is based on other biophysical or physicochemical mechanisms.

BIBLIOGRAPHY

1. Belenkov, N. Yu., Chirkov, V. D. and Syzganov, A. I., ZHURN. VYSSH. NERVN. DEYAT., 1977, No 1, pp 137-146.

2. Dmitriyeva, N. V., Kuleshov, Ye. V. and Ordzhonikidze, E. K., Ibid, 1968, No 3, pp 463-468.

3. Kachkinbayev, K. B., Abdullina, Z. M. and Dzhunushev, M. D., in "Vliyaniye magnitnykh poley na biologicheskiye obyekty" [Effect of Magnetic Fields on Biological Systems], Kaliningrad, 1975, p 101.

4. Klimovskaya, L. D. and Smirnova, N. P., BYUL. EKSPER. BIOL., 1976, No 8, pp 906-910.

5. Lyutov, S. I. and Gavrilushkin, A. P., in "Strukturno-funktsionalnyye mekhanizmy korkovoy integratsii" [Structural and Functional Mechanisms of Cortical Integration], Gorkiy, 1976, pp 69-72.

6. Smirnova, N. P. and Klimovskaya, L. D., ZHURN. VYSSH. NERVN. DEYAT., 1976, No 2, pp 403-410.

7. Smirnova, N. P., Klimovskaya, L. D. and Dyakonov, A. S., KOSMICHESKAYA BIOL., 1982, No 4, pp 61-63.

8. Kholodov, Yu. A., "Nervous System Reactions to Electromagnetic Fields," Moscow, 1975.

9. Chirkov, V. D., Gavrilushkin, A. P., Lyutov, S. I. et al., in "Proyektsionnyye i assotsiativnyye sistemy mozga" [Projection and Associative Systems of the Brain], Moscow, 1977, pp 143-147.

UDC: 629.78:616.12-008.318-092.9-084

EXPERIMENTAL ARRHYTHMIA AND ITS PREVENTION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 20 Nov 84) pp 64-68

[Article by L. L. Stazhadze, T. A. Ventslavskaya and V. V. Korzhova]

[English abstract from source] The preventive anti-arrhythmic effect of a new derivative of selene-containing aralkyl amines, i.e., selenophene-24, was compared with the routinely used drugs--novocain amide, isoptin and inderal. With respect to the preventive effect and spectrum of action selenophene-24 was shown to be advantageous on various experimental models of arrhythmias: aconitinum, strophantinum, pituitrinum or calcium chloride.

[Text] Data accumulated to date concerning functional changes in different systems of the body that arise during spaceflights make it necessary to develop methods and means of pharmacological correction of these changes.

The cardiovascular system is exposed to considerable factors in cosmonauts (particularly during long-term missions) [5, 11, 18]. Functional changes are observed in the sympathetic nervous system and the heart itself during spaceflights [7, 9, 14, 17]. It is of first and foremost significance to space pharmacology to search for cardiotropic drugs that normalize heart rate and restore its regulatory mechanisms.

Since onset of arrhythmia is often associated with various disturbances in condition of the membrane of cardiomyocytes, their electric properties and transmembrane transport of ions, it is necessary to proceed from presence of membranotropic properties when assessing the expediency of a search for antiarrhythmia agents [13, 16].

It has been reported that selenium compounds have the capacity to prevent changes in cell membranes and, consequently, to preserve viability of cells [4, 12].

Our objective here was to make a comparative evaluation of the preventive antiarrhythmic effect of selenophene-24, a derivative of selenium-containing aralkyl amines, to known antiarrhythmia agents. We used novocainamid, inderal and isoptin as standards.

Methods

We evaluated the preventive antiarrhythmia and antifibrillation activity of the tested agents according to their capacity to prevent onset of experimental arrhythmia elicited by aconitine, strophanthin, pituitrin and calcium chloride.

The study was conducted on 90 hybrid white rats weighing 150-240 g and 430 hybrid white mice weighing 20-25 g. Four series of experiments were performed.

In the 1st series, arrhythmia was induced in hybrid white rats (90 specimens) by intravenous injection of aconitine in a dosage of 40 μg/kg. To prevent arrhythmia, the tested agents were injected intraperitoneally 20 min prior to aconitine in the following doses: selenophene-24, 1 and 5 mg/kg (minimum and maximum effective, constituting 1/120 and 1/24 of LD_{50}); novocainamid, 40 and 60 mg/kg; and inderal, 4 mg/kg. Preventive antiarrhythmic activity of these agents was assessed by the nature of arrhythmia, its duration and survival of animals.

In the 2d series of experiments, we produced strophanthin arrhythmia in 109 white mice, using 0.05% ampullated solution of strophanthin K, which was injected in the caudal vein in a dosage of 60 μg/kg, with additional subsequent injections at the rate of 10 μg/kg every 10 min until persistent ventricular arrhythmia appeared [1]. To assess the preventive action of the tested agents, they were injected intravenously 1-3 min before the first strophanthin injection. Increase in arrhythmogenic and lethal doses of strophanthin served as a criterion of efficacy of the agents.

In the 3d series of experiments, acute cardiac ischemia and arrhythmia were induced in white mice by intravenous injection of pituitrin in a dosage of 1 U/kg, and the tested agents were administered 20 min prior to this injection. Product activity was assessed according to nature and duration of arrhythmia.

In the 4th series, preventive antifibrillation action of selenophene-24, as opposed to the activity of isoptin, was tested on the most "rigid" calcium chloride model of arrhythmia, which was induced by forced intravenous injection of calcium chloride in a dosage of 280 mg/kg in white mice.

Animals, in which one of the models of arrhythmia was induced without prior administration of antiarrhythmic agents, served as controls for each series. Cardiac rhythm disorders were recorded on an Elkar-6 electrocardiograph in the thoracic lead, at paper feed rate of 50 mm/s.

Quantitative analysis of the ECG (variational pulsogram) was performed by the method of R. M. Bayevskiy and B. I. Polyakov [3]. We assessed cardiac rhythm in the 1st, 5th, 10th, 20th, 30th and 60th min.

In addition, we calculated the therapeutic index (LD_{50}/effective dose) in order to evaluate the range of therapeutic action of the tested agents.

Results and Discussion

With preventive administration of selenophene-24 against aconitine-induced arrhythmia, we demonstrated a substantial influence on the course and outcome of arrhythmia. Thus, in a dosage of 1 mg/kg, selenophene-24 reduced the duration of aconitine arrhythmia to almost 1/4 of the control (from 115.0±8.4 to 24.5±5.8 min; $P<0.01$), whereas in a dosage of 5 mg/kg it restored proper sinus rhythm in 18.2±4.0 min. In all cases, selenophene-24 prevented development of lethal fibrillation of the heart. Animal survival rate rose to 100%, versus 67% in the control.

Novocainamid had no beneficial preventive effect on aconitine arrhythmia. Other authors obtained analogous results [8, 15].

Inderal depressed ectopic rhythm in the presence of aconitine arrhythmia and reduced its duration to 1/3, as compared to the control. However, like novocainamid, inderal did not eliminate lethal fibrillation of the heart and did not prevent animal death, and this is consistent with the findings of several authors [2, 15].

Table 1.
Changes in arrhythmogenic and lethal doses of strophanthin K with prior administration of selenophene-24, novocainamid and inderal to white mice

Experimental conditions	Number of experim.	Dosage, mg/kg	Strophanthin arrhythmogenic dose, mg/kg	Median lethal dose of stroph. in mice, mg/kg
Control	22		0,07±0,009	0,15±0,02
Selenophene-24	25	1	0,13±0,001*	0,20±0,009*
	20	5	0,14±0,008*	0,21±0,001*
Novocainamid	20	10	0,10±0,02	0,17±0,02
Inderal	22	1	1,17±0,009*	0,24±0,002*

* $P<0,05$.

The experimental results warrant the belief that selenophene-24 is the most effective agent in prevention of aconitine arrhythmia in rats; in all cases, it depressed the ectopic excitation site and restored sinus rhythm to the heart.

With injection of toxic doses of strophanthin K to mice there were typical signs of rhythm disorders: appearance of bradycardia, impairment of atrioventricular conduction, onset of ventricular extrasystoles. The tested agents differed in protective effect on strophanthin poisoning.

Novocainamid raised insignificantly the arrhythmogenic and lethal dose of strophanthin (Table 1). However, in the case of strophanthin-induced ventricular tachycardia, it not only failed to elicit an antiarrhythmic effect, but caused fibrillation of the ventricles.

Inderal reliably raised the threshold of strophanthin action (by 2.5- times) and survival time of animals with poisoning (see Table 1).

It was established that the arrhythmogenic dose of strophanthin increased 2-fold and lethal dose, 1.3-1.4-fold with preventive administration to mice of selenophene-24 in doses of 1 and 5 mg/kg (see Table 1).

Thus, selenophene-24 attenuated appreciably the toxic effect of strophanthin, showing greater activity than novocainamid, but less than inderal in an equivalent dose. Several studies have shown that inderal, being a β-adrenoblocking agent, has marked antiarrhythmic activity against strophanthin-induced arrhythmia [6, 10].

Administration of pituitrin to white mice led to appearance of coronary insufficiency, with which there was development of arrhythmia in the form of disturbances referable to automatism function (sinus bradycardia), conduction (atrioventricular block) and excitability (extrasystole).

Preventive administration of selenophene-24 in a dosage of 1 mg/kg altered the nature of cardiac ischemia and arrhythmia. After giving pituitrin following selenophene-24, the heart rate decreased to almost one-half; however, it was higher (240±8.2/min) than in control animals (120±16.4/min; $P<0.01$). Duration of arrhythmia averaged 18.4±3.6 min, whereas in the control it lasted 2.5 times longer (50.5±4.8 min). After restoration of correct sinus rhythm, heart rate came close to the baseline.

With increase in selenophene-24 dosage to 5 mg/kg, we succeeded in attenuating appreciably the toxic effect of pituitrin, and this resulted in a mild course of ischemia and arrhythmia: only 6 out of 22 mice presented an incomplete atrioventricular block, which changed to bradycardia and proper sinus rhythm.

Novocainamid in a dosage of 40 mg/kg proved to be an ineffective agent against pituitrin arrhythmia, having a mild effect on cardiac automatism (heart rate).

In a dosage of 2 mg/kg, inderal distinctly reduced arrhythmia from 50.5±4.8 to 20.8±8 min.

The results of our study of the effects of agents on the experimental model of pituitrin arrhythmia enable us to conclude that selenophene-24 and inderal elicit not only an antiarrhythmic, but marked anti-ischemic effect.

V. V. Frolkis et al. [16] attribute the mechanism of pituitrin arrhythmia to significant changes in lipid composition and calcium pump of the sarcoplasmic reticulum. For this reason, the antiarrhythmic effect of drugs with administration of vasopressin is interpreted by the authors as the result of normalization of membrane permeability due to the antioxidant action of the agents.

Since it has been established that selenophene derivatives--antioxidants--have a stabilizing effect on lipids of intracellular membranes [12], the antiarrhythmic effect of selenophene-24 can also be explained by this mechanism of action.

Intravenous injection of calcium chloride in a dosage of 280 mg/kg led to ventricular fibrillation and instantaneous death of the animals. After injection of calcium chloride, the variational range (index of arrhythmia) increased 500-fold (7.5±0.6 s, versus baseline of 0.015±0.0007 s; $P<0.01$). There was concurrent 3-fold increase in mode, while the amplitude of mode, ratio of mode amplitude to arrhythmia index and tension index, on the contrary, decreased significantly (Table 2). This is indicative of dramatic activation of the humoral channel and parasympathetic branch of the autonomic

nervous system, which was associated with considerable weakening of mechanisms of regulation of heart rhythm at the moment preceding cardiac arrest.

Table 2. Parameters of heart rate with preventive use of isoptin and selenophene-24 on a calcium chloride model of arrhythmia (M±m)

Experimental conditions	Number of animals	Time after giving agent min	Range of variations (arrhythmia index)-- ΔX, s	Cardiac interval-Mo, s	Share of cardiac intervals corresponding to mode-AMo, %	AMo/ΔX	Tension index-- TI= Amo/2ΔX·Mo
Baseline	237		0,015±0,003	0,17±0,02	46±12	2942±440	10605±242
Calcium chloride, 280 mg/kg	57	1	7,5±0,6**	0,52±0,1**	13±7,4**	17±6,3**	86±54**
Isoptin, 1 mg/kg	85	1	0,018±0,006	0,19±0,05	48±10,5	3081±127	11359±642
		2	0,017±0,006	0,22±0,06	39±7,9	2854±132	6101±417
		20	0,024±0,005	0,23±0,07	36±5,2	2089±622	5495±161
Calcium chloride, 280 mg/kg		1	4,8±0,8**	0,44±0,5*	15±5,8*	21±10**	155±125**
		2	0,26±0,015**	0,23±0,02*	23±8,8	969±777*	2720±204**
		5	0,103±0,03*	0,22±0,04	28±7,5	866±15,2**	2506±134**
		30	0,03±0,03	0,31±0,04*	36±2,9	2189±105	7027±247
Selenophene-24, 1 mg/kg	95	1	0,016±0,003	0,16±0,02	44±7,5	3490±934	10612±717
		5	0,013±0,002	0,19±0,03	44±1,7	3634±605	10377±208
		20	0,016±0,002	0,22±0,02	53±10	3398±110	8484±408
Calcium chloride, 280 mg/kg		1	3,32±1,8**	0,33±0,05	15±3,7*	24±9,3**	168±23**
		2	0,16±0,12*	0,23±0,08	25±9,2	1495±125	4695±422*
		5	0,03±0,02	0,23±0,05	34±11	2303±369	6451±369
		30	0,03±0,02	0,26±0,08	46±4,6	4652±310	11292±415

* $P<0,05$.
** $P<0,01$.

We observed a tendency toward slowing of heart rate 20 min after intraperitoneal injection of isoptin in doses of 1 and 5 mg/kg to intact animals. Subsequent injection of calcium chloride revealed that, in a dosage of 1 mg/kg, isoptin elicited a preventive effect in 50% of the cases; however, heart rate did not revert to the base level. In a dosage of 5 mg/kg, isoptin led to normalization of heart rate in 80% of the cases; in 20% of the tests, the animals developed cardiac arrest.

Analysis of the ECG revealed that the arrhythmia index rose dramatically, to 4.8±0.008 s after administration of an absolutely lethal dose of calcium chloride following isoptin (0.024±0.005 s in the 20th min after isoptin; $P<0.01$). This was associated with activation of the influence of the parasympathetic branch of the autonomic nervous system with inhibition of the sympathetic branch and attenuation of regulatory mechanisms. However, by the 5th min, there was some attenuation of parasympathetic influence and onset of influence of the sympathetic branch of the autonomic nervous system, but the tension index was restored only by the 30th min (see Table 2).

With administration of calcium chloride (280 mg/kg) after selenophene-24 (1 mg/kg), cardiac arrest was observed in only 4% of the mice, whereas in 96% of the experiments we demonstrated a marked antifibrillation effect. There was complete restoration of rhythm and strength of cardiac contractions already by the 2d min.

In a dosage of 5 mg/kg, selenophene-24 had a preventive antiarrhythmic effect in 100% of the cases. By the 2d-5th min, many parameters of heart rhythm came close to the baseline, unlike those associated with use of isoptin (see Table 2).

Thus, The capacity in selenophene-24 to prevent the fibrillatory effect of calcium chloride, which was quantitatively manifested by increase in survival rate of animals (percentage), is a reliable criterion for evaluation of preventive antiarrhythmic activity of the agent.

Table 3. Therapeutic indexes of selenophene-24, novocainamid, inderal and isoptin in experimental models of arrhythmia

Experimental conditions	Arrhythmia induced by			
	aconitine (rats)	strophanthin (mice)	pituitrin (mice)	calcium chloride (mice)
Selenophene-24	120.9	48.3	120.9	24.1
Novocainamid		2.7		
Inderal	24.2	29.9	48.4	
Isoptin				14.4

Table 3 lists comparative activity of antiarrhythmic agents in the presence of various types of arrhythmia according to therapeutic indexes. It was established that the range of the therapeutic index for selenophene-24 is 5 times greater with aconitine arrhythmia than with inderal. The therapeutic index was not established for novocainamid with aconitine arrhythmia, since novocainamid was not very effective in the tested doses. In the case of strophanthin arrhythmia, selenophene-24 was 18 and 1.5 times more active as antiarrhythmic than novocainamid and inderal, respectively. A comparison of therapeutic indexes with pituitrin arrhythmia revealed that the antiarrhythmic activity of selenophene-24 was 2.7 times greater than that of inderal. The range of the therapeutic effect of selenophene-24 in preventing calcium chloride arrhythmia was 1.7 times wider than for isoptin.

Thus, it was demonstrated on different models of experimental arrhythmia that selenophene-24 elicits a greater therapeutic effect than the known antiarrhythmics (novocainamid, inderal and isoptin), and it is the optimum prophylactic agent against arrhythmia.

BIBLIOGRAPHY

1. Ammar, E. M. and Kudrin, A. N., in "Vsesoyuznyy syezd farmatsevtov. 2-y. Trudy" [Proceedings of 2d All-Union Congress of Pharmacists], Moscow, 1969, p 82.

2. Aslanyants, Zh. K. and Kudrin, A. N., KARDIOLOGIYA, 1974, No 1, pp 98-103.

3. Bayevskiy, R. M. and Polyakov, B. I., FIZIOLOGIYA CHELOVEKA, 1978, No 6, pp 1096-1098.

4. Beketova, T. P. and Chernysheva, L. F., in "Selen v biologii" [Selenium in Biology], Baku, 1976, Bk 1, p 42.

5. Vorobyev, Ye. I., Gazenko, O. G. and Gurovskiy, N. N., KOSMICHESKAYA BIOL., 1976, No 5, pp 3-18.

6. Gatsura, V. V. and Kudrin, A. N., "Serdechnyye glikozidy v kompleksnoy farmakoterapii nedostatochnosti serdtsa" [Cardiac glycosides in Combined Pharmacotherapy of Cardiac Insufficiency], Moscow, 1983.

7. Dietlein, L., Rambaut, O. and Nicogossian, A., KOSMICHESKAYA BIOL., 1984, No 1, pp 8-14.

8. Zakusov, V. V., Pryanishnikova, N. T., Chernyakova, I. V. et al., FARMAKOL. I TOKSIKOL., 1983, No 5, pp 32-37.

9. Kvetnansky, R. C. and Tigranyan, R. A., KOSMICHESKAYA BIOL., 1982, No 1, pp 80-83.

10. Kostin, Ya. V., "Investigation of Antiarrhythmic Action of Some Anesthetics and Antiadrenergic Agents," author abstract of candidatorial dissertation in medical sciences, Kazan, 1977.

11. Krupina, T. N., Yarullin, Kh. Kh., Artamonova, N. P. et al., KOSMICHESKAYA BIOL., 1984, No 4, pp 29-32.

12. Kudrin, A. N., Levshin, B. I. and Mekhtiyev, M. A., "Farmakoterapiya preparatami selena eksperimentalnogo gepatita" [Pharmacotherapy of Experimental Hepatitis With Selenium Formulations], Baku, 1982, p 175.

13. Lukyanenko, N. G., Bogatskiy, A. V., Yaroshchenko, I. M. et al., FARMAKOL. I TOKSIKOL., 1984, No 5, pp 29-31.

14. Stazhadze, L. L., Goncharov, I. B., Neumyvakin, I. P. et al., KOSMICHESKAYA BIOL., 1982, No 4, pp 9-12.

15. Urbayte, E. N., "Antiarrhythmic Activity of Some Newly Synthesized Benzodioxan-1,4 Derivatives," author abstract of candidatorial dissertation in medical sciences, Kaunas, 1976.

16. Frolkis, V. V., Frolkis, R. A., Dubur, G. Ya. et al., FARMAKOL. I TOKSIKOL., 1983, No 6, pp 20-24.

17. Yarullin, Kh. Kh., Vasilyeva, T. D., Turchaninova, V. F. et al., KOSMICHESKAYA BIOL., 1984, No 4, pp 22-28.

18. Johnson, W. E., in "Chelovek v kosmose" [Man in Space], Moscow, 1974, pp 142-159.

UDC: 629.78:612.79

EVALUATION OF CONDITION OF HUMAN SKIN IN A CLOSED ENVIRONMENT BY MEANS OF CHROMATOGRAPHY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 13 Jul 84) pp 69-73

[Article by D. M. Dubinin, V. P. Naydina and S. N. Zaloguyev (deceased)]

[English abstract from source] Gas-liquid chromatography was used to study the skin and sebum cutaneum of 6 male test subjects (aged 45-55) before and after 30-day enclosure. The greatest changes were seen in the composition of free fatty acids of lipids of the facial skin (increase of palmito-oleic acid). The lipid composition of the sebum cutaneum of the healthy subjects differed from that of the acne-bearing subjects. It is recommended to use the ratio of palmitic acid to palmito-oleic acid as a measure of changes of fatty acids in the sebum cutaneum of healthy people in an unusual environment.

[Text] Exposure of man to spaceflight factors could be instrumental in onset of adverse changes in the integument [1-3, 6, 18]. The causes of this phenomenon have not been sufficiently investigated [6, 8]. We report here on a study of the composition of the most active fraction of lipids of the skin surface, free fatty acids [5, 11, 14], in which we used gas-liquid chromatography [GLC]. Changes in the above-mentioned parameters were compared to findings from a clinical examination of the skin and subjective evaluation of efficacy of personal hygiene methods.

Methods

A total of 6 subjects 45-55 years of age participated in our study; they spent 30 days in a closed environment. Microclimate parameters: air temperature 20±2°C, ambient humidity 50±20%, composition of gas atmosphere--21±2% O_2 and 3±0.1% CO_2.

Sanitary and hygienic care of the skin included a shower taken once every 10 days using washcloths saturated with shampoo, daily care of the facial and arm skin using tap water and hand soap. The amount of water used was not restricted. The skin of the face, arms and back was submitted to clinical examination 1 day before the start of the studies and immediately after

the stay in a closed environment. Concurrently, we took samples of cutaneous sebum for gas-chromatographic analysis. On the 11th, 21st and 30th days of the stay in the closed environment, the subjects were interrogated following a specially developed method in order to make a physiological and hygienic evaluation of the skin and efficacy of showering procedures.

Many authors [1, 6, 18] have shown that exposure of man to the factors in a closed environment quite often elicits appearance of blackheads and even furuncles. To examine this phenomenon, we tested lipids from the facial skin surface of 12 patients with the papulopustulous form of blackheads.

Samples of cutaneous sebum for chromatographic analysis were taken from the skin of the face, dorsal aspect of the palm of the hand, interscapular region of the back by the washing method 12 h after taking a shower, using mixtures of ethyl alcohol and ethyl ether in a 1:2 ratio.

Washings were stored at -5° temperature for use in subsequent tests.

Methyl ethers of free fatty acids were recovered using reagent BF_3 in methanol (14% solution) of the Merck Company. Quantitative assay of fatty acids was made by the method of endogenous normalization [7].

We used a Tsvet-100 chromatograph with ionization-flame detector and glass column 4 m long filled with diethyleneglycol succinate in gasochrome Q. The velocity of nitrogen gas carrier was 50 mℓ/min, hydrogen 40 mℓ/min and air 300 mℓ/min. Column temperature 180°C.

Results and Discussion

In the baseline period the subjects presented moderate secretion of cutaneous sebum. There were poorly marked orifices of sebaceous hair follicles, and occasionally we found sebaceous plugs in the nasal skin. The skin of the forehead, cheeks and chin was smooth and clean. There was also moderate secretion of sebum in the dorsal skin; as a rule, the excretory ducts of sebaceous hair follicles were open and marked in the interscapular region. Thus, the baseline clinical findings were indicative of absence of pathological changes in the subjects' skin.

On the 7th-10th day after taking a shower in the confined room, most subjects reported considerable soiling of the scalp, appearance of dandruff, which was apparently related to the natural process of accumulation of lipids on the skin before reaching a saturation level [1, 4, 6]. After each shower, the unpleasant sensations of unclean and oily scalp disappeared.
All of the subjects reported that it was convenient to use the washcloths with shampoo and that they felt better after using them. Clinical examination revealed that the personal hygiene regimen and agents provided for a satisfactory skin condition throughout the test period.

Examination of free fatty acid content of lipids of the skin surface by gas chromatography (Table 1) revealed that palmitic, palmitoleic, oleic and lignoceric acids were the main constituents of cutaneous sebum. In all segments of the skin, fatty acids with 14 to 19 (C_{14-19}) atoms of carbon

constituted 60-70% and those with 20 to 24 (C_{20-24}), 30-40%. The share of saturated acids constituted 65-70% and unsaturated, 30-35%.

Table 1. Free fatty acid content (rel.%) of lipids in skin surface of the face, back and hands of men before (baseline) and after (exit) stay in closed environment (n = 6)

Code for acid	Face		Back		Hand	
	baseline	exit	baseline	exit	baseline	exit
14:0	3,68	4,80	4,52	4,45	3,70	4,17
15:0	5.01	7,39	3,73	5,83	3,53	3,97
16:0	17,96	22,34	22,48	33,36	21,89	23,69
16:1	13,88	18,98	10,48	13,47	11,85	13,96
18:2+19:0	0,89	1,30	0,82	0,66	0,48	0,87
18:0	4,32	4,26	5,46	5,24	7,13	6,90
18:1	13,93	15,35	13,64	12,05	16,83	19,20
18:2+19:0	4,51	3,93	4,33	3,51	4,63	5,86
20:0	0,79	0,24	0,62	0,48	0,91	0,26
21:0	1,56	0,78	0,79	0,08	0,43	0,78
Unidentified	0,48	0,14	0,19	—	0,31	0,22
22:0	3,59	1,28	4,33	1,32	4,29	2,49
23:0	4,93	4,89	7,16	5,12	4,99	8,76
24:0	24,50	14,29	21,69	14,44	18,98	8,88
C_{14-19} ($M\pm m$)	64,16±2,47	78,36±1,71*	65,22±3,98	76,56±2,67**	70,04±1,33	78,62±2,26
Saturated ($M\pm m$)	66,32±1,83	60,30±1,25***	70,78±1,93	70,31±1,87	65,85±2,15	59,92±2,36

* $P<0,001$.
** $P<0,02$.
*** $P<0,002$.

Significant amounts of C_{20-24} fatty acids were contained in washings from the tested skin areas. Analogous findings for other parts of the skin are reported by Bussel [10], and for this reason it is expedient to take into consideration the amount of long-chain fatty acids when studying lipids of the skin surface.

Figures 1 and 2 illustrate chromatograms of methyl ethers of free fatty acid of facial and dorsal skin before and after the tests. We demonstrated changes in fatty acid composition of lipids of the skin surface. We calculated the following parameters to assess changes in levels of fatty acids: ratio of C_{14-19} fatty acids to C_{20-24} (K_1), ratio of total saturated to total unsaturated acids (K_2), ratio of palmitic acid content to palmitoleic (K_3). The parameters calculated from chromatograms of methyl ethers of lipid fatty acids on the skin surface before and after the subjects' stay in the closed environment are listed in Table 2.

We demonstrated (see Figures 1, 2 and Tables 1, 2) significant increase in relative amounts of C_{14-19} fatty acids, decrease in C_{20-24} on all skin areas and corresponding changes in K_1. The decrease in saturated acids occurred primarily at the expense of lignoceric acid with concurrent increase in unsaturated fatty acid content over all skin areas. Bore [9] has shown that lipids recovered from the scalp of individuals with oily hair contained more unsaturated fatty acids than saturated, as compared to

individuals with normal and, particularly, dry hair. The demonstrated changes in proportion of saturated and unsaturated fatty acids could be indicative of increased oiliness of the scalp.

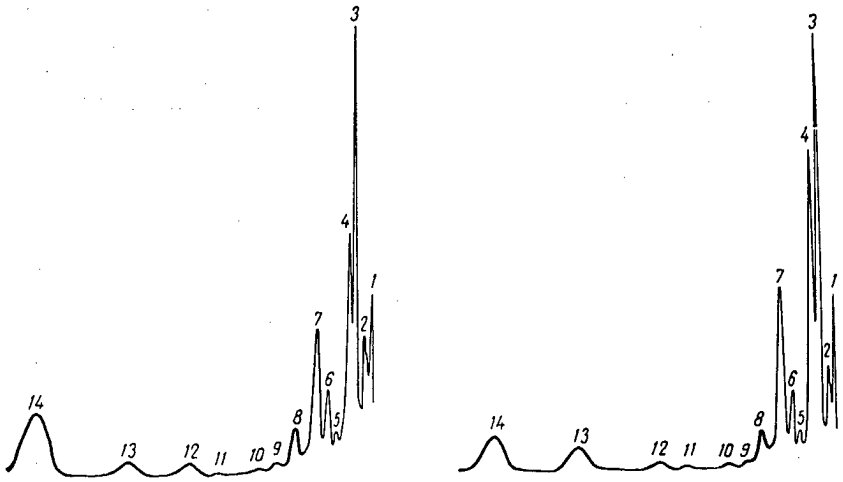


Figure 1. Chromatograms of methyl ethers of lipid free fatty acids of facial skin surface

Here and in Figures 2 and 3:

a, b) before and after the tests, respectively

1) myristic (14:0)
2) pentadecanoic (15:0)
3) palmitic (16:0)
4) palmitoleic (16:1)
5) (17:0 + 16:2)
6) stearic (18:0)
7) oleic (18:1)
8) (19:0 + 18:2)
9) arachic (20:0)
10) (21:0)
11) unidentified
12) behenic (22:0)
13) (23:0)
14) lignoceric (24:0)

Table 2. Composition of free fatty acids (K_1, K_2, K_3) of lipids on skin surface of the face, back and hands of men before and after stay in closed environment (M±m)

Parameter	Face		Back		Hand	
	baseline	exit	baseline	exit	baseline	exit
K_1	2,02—0,19	3,75 0,34*	2,07 0,36	4,34 1,12	2,37 0,15	3,94 0,51
K_2	2,02 0,17	1,53 0,08**	2,49 0,20	2,44 0,22	1,78 0,19	1,53 0,13
K_3	1,42 0,19	1,25 0,16	2,25 0,20	2,60 0,29	2,15 0,32	1,87 0,27

* $P<0,002$.
** $P<0,05$.

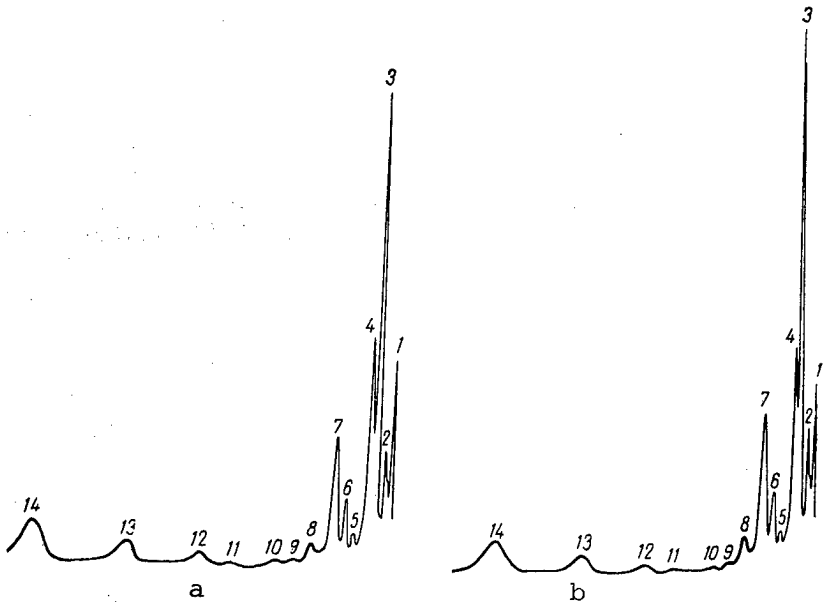


Figure 2. Chromatogram of methyl ethers of lipid free fatty acids on dorsal skin surface

According to data in the literature, free fatty acids have bactericidal properties [14-17]. Noren [15] established that the lipid excretions of M. xanthus have an antagonistic effect on fungi; they consist of 68% saturated and 32% unsaturated acids. It is known that saturated acids have greater antibacterial properties than unsaturated ones [16, 17]. The noted decrease in amount of saturated fatty acids could have led to decline of bactericidal properties of the skin.

Analysis of parameters K_1 and K_2 (see Table 2) revealed that there were identical changes in lipid composition in all tested skin areas before and after the experiments. Evaluation of changes in K_3 revealed that it decreased after the tests on the skin of the face and hands, and increased on the dorsal skin. As can be seen in Table 1, unlike the skin of the face and hands, the dorsal skin showed 1.5-fold increase in palmitic acid.

Evaluation of proportion of palmitic and palmitoleic acids in washings from the scalp was made by Goetz et al. [12]. These authors relate the decline of parameter K_3 to the activity of lypolytically active microflora of the skin. The demonstrated changes may be related to increase in amount or in lipolytic activity of skin microflora.

According to the data in [13], fatty acids with 10 to 18 atoms of carbon have comedogenic activity, and monounsaturation enhances these properties. Thus, the reliable increase in palmitoleic acid content observed during stays in closed environments could lead to development of comedos.

In subjects with blackheads, the latter were localized mainly on the face. There was increased secretion of sebum on the face and the orifices of the

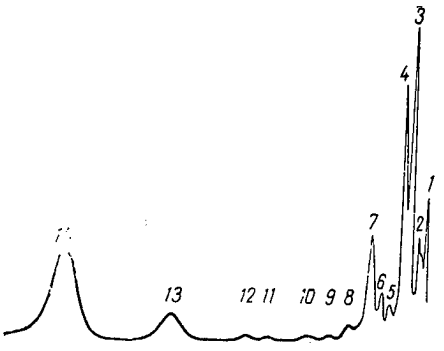


Figure 3.
Chromatogram of methyl ethers of lipid free fatty acids on skin surface of a patient with comedos

sebaceous hair follicles were drastically dilated. There were numerous open comedos on the skin surface in the form of dark brown and black plugs. The pustular eruptions consisted of red cone-shaped nodules 2-4 mm in diameter. They were transformed mainly from papular elements. There was an insignificant inflammatory infiltrate at their base. Gradually disappearing static-cyanotic spots were observed at the sites of resolution of papular elements. In a number of instances, there were isolated closed comedos, along with open ones. Figure 3 illustrates a typical chromatogram of methyl ethers of free fatty acids in lipids of skin surface in subject with blackheads.

Analysis revealed that lipids of the facial skin in cases with comedos contain significant amounts of palmitoleic acid. In these cases, K_3 was lower (1.01±0.44) than in healthy subjects (1.42±0.19; see Table 2).

One should consider that this parameter is typical of the composition of free fatty acids of facial skin surface lipids in cases with blackheads, and that it can be used to assess changes in fatty acid content of sebum of healthy people exposed to extreme factors and in studies of regimens and means of personal hygiene.

The above-mentioned decline of K_2 to 1.25 on the facial skin of subjects after 30 days in a closed environment indicates that the changes that occurred in the skin were analogous to those observed in patients with blackheads and are indicative of a predisposition to such pathology. For this reason, it is necessary to work out some special means of hygiene. Thus, it was established that GLC permits detection of changes in composition of cutaneous sebum resulting from the factors involved in a closed environment, and GLC can be recommended for evaluation of personal hygiene regimens and methods.

BIBLIOGRAPHY

1. Borshchenko, V. V., in "Osnovy kosmicheskoy biologii i meditsiny" [Bases of Space Biology and Medicine], Moscow, 1975, Vol 3, pp 122-140.

2. Gorshkov, V. P., Zhidkov, V. V., Shumilina, G. A. et al., in "Aktual'nyye voprosy kosmicheskoy biologii i meditsiny" [Pressing Problems of Space Biology and Medicine], Moscow, 1971, Vyp 1, pp 94-95.

3. Zaloguyev, S. N., Viktorov, A. N. and Startseva, N. D., in "Problemy kosmicheskoy biologii" [Problems of Space Biology], Moscow, 1980, Vol 42, pp 80-120.

4. Korolev, Yu. F., "Seboreya i ugri" [Seborrhea and Blackheads], Minsk, 1972.

5. Mitruka, B. M., "Primeneniye gazovoy khromatografii v mikrobiologii i meditsine" [Use of Gas Chromatography in Microbiology and Medicine], Moscow, 1978.

6. Popov, I. G., Borshchenko, V. V., Savinich, F. K. et al., in "Problemy kosmicheskoy biologii," Moscow, 1967, Vol 7, pp 413-420.

7. Stolyarov, B. V., Savinov, I. M. and Vitenberg, A. G., "Rukovodstvo k prakticheskim rabotam po gazovoy khromatografii" [Manual of Practical Gas Chromatography], 2d ed., Leningrad, 1978.

8. Shumilina, G. A., Zarubina, K. V., Gorshkov, V. P. et al., in "Aktual'nyye voprosy kosmicheskoy biologii i meditsiny," Moscow, 1971, Vyp 1, pp 287-289.

9. Bore, P., Goetz, N. and Caron, J. C., INT. J. COSMET. SCI., 1980, Vol 2, pp 177-191.

10. Bussel, N. E., Gron, A. and Miller, R. A., GOVERNMENT REP. ANNOUNCEM. INDEX, 1979, No 12, p 85.

11. Downing, D. T. and Straun, J. S., J. INVEST. DERM., 1974, Vol 62, pp 228-244.

12. Goetz, N., Kaba, G. and Bore, P., J. CHROMATOGR. BIOMED. APPL., 1982, Vol 233, pp 19-28.

13. Kligman, A. M., Wheatley, V. R. and Mills, O. H., ARCH. DERM., 1970, Vol 102, pp 267-275.

14. Nicolaides, N., SCIENCE, 1974, Vol 186, pp 19-26.

15. Noren, B. and Adham, G., LIPIDS, 1973, Vol 8, pp 573-578.

16. Nowak, A. F. and Clark, G. C., DUPUY. OIL SOAP, 1961, Vol 38, pp 321-324.

17. Puhvel, S. M. and Reisner, R. M., J. INVEST. DERM., 1970, Vol 54, pp 48-52.

18. Slonim, A. R., AEROSPACE MED., 1966, Vol 37, pp 1105-1114.

UDC: 629.78:615.917:678].07

TOXICOLOGICAL EVALUATION OF GAS EMISSION FROM HEAT-STABLE TETRAFLUOROETHYLENE-BASED POLYMERS WHEN HEATED

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 4 Oct 84) pp 73-77

[Article by V. F. Ushakov, G. I. Solomin, G. P. Tikhonova, A. I. Gorshunova, I. I. Lyubarskaya, L. V. Marchenko, E. I. Chukhno, N. Ye. Ostasheva, Ye. A. Demchenko and S. S. Pashin]

[English abstract from source] The purpose of this study was to investigate the composition and toxicity of fluoroplastic F-40 thermodestruction products at 300-500°C and to identify the maximally allowable temperature for their safe use. When heated over 400°C, the products of fluoroplastic F-40 evolution included such compounds as hydrogen fluoride, fluoro-organic compounds, carbon monoxide, formaldehyde. When heated at 500°C, the thermodestruction products caused the highest mortality rate of mice. The pathogenesis and clinical development of fluoroplastic F-40 poisoning are primarily associated with fluoro-compounds. It is concluded that the temperature 300°C is the maximum temperature at which tetrafluoroethylene-based polymers can be used.

[Text] At the present time, industry puts out fluoroplastics based on tetrafluoroethylene and chlorotrifluoroethylene. By virtue of high chemical stability, mechanical and dielectric properties, they are finding broad applications in electronics, electric engineering, and they are also used in space vehicles. Although the polymers in this group are thermostable, they can ignite and emit toxic substances.

Analysis of the literature [1, 3, 7, 8] concerning the effect on man of heat-stable polymers based on tetrafluoroethylene shows that there are still insufficient data for objective evaluation of the hazard of gas emissions from these materials at high temperatures. There has also been little work written about the composition and toxicity of volatile agents released from simple fluoroplastic at temperatures causing their thermal destruction (melting of surface of sample, partial loss of its weight, onset of fluidity). It is known that, at temperatures up to 40°C, fluoroplastics are not a source of air pollution by volatile chemicals [4]. Heating fluoroplastics for 1 h to a temperature of 200°C caused emission into

the atmosphere of several micrograms of organically bound fluorine [6]. Deviations in health status are induced in workers upon contact with fluoroplastic heated to 400°C. Subjectively, they complain of chills, pressure in the chest, dry cough, irritation of the upper respiratory tract and objectively, there is temperature elevation to 39.5-40°C, faster pulse, moderate neutrophil leukocytosis and faster erythrocyte sedimentation rate [1, 7, 8]. Experiments on mice showed that 5-min inhalation of products emitted during heat-destruction of the polymer at 600°C and saturation of 130 mg/ℓ leads to death of 50% of the animals [2]. In the course of combustion, fluoroplastics emit hydrogen fluoride, organofluorine compounds, methane, carbon monoxide and dioxide, and other toxic substances into the air environment [3, 5].

We report here the results of a study of composition and toxicity of gas emissions from tetrafluoroethylene-based heat-stable polymers heated to 300 to 500°C. This will make it possible to validate the maximum allowable temperature for their use on the basis of health and hygiene parameters.

Methods

We tested fluoroplastic F-40 in the form of sheets 5-7 mm thick. A sample batch constituted 4.160±0.002 g, which corresponded to polymer saturation of 130 mg/ℓ. The sample was heated in a flow of air, the velocity of which was 0.5 ℓ/min. The formed products of thermal-oxidative breakdown (PTOB) were fed into the chamber with the animals. Animal inhalation time equaled polymer heating time. Thus, it constituted 20 min at temperatures of 300 and 350°C, and 10 min at 400, 450 and 500°C. We measured carbon monoxide and dioxide, hydrogen fluoride, organofluorine compounds, formaldehyde and volatile organic compounds (total, based on carbon) in the gas emissions. During the inhalation period, we monitored the percentage of oxygen in the chamber atmosphere. Sanitary and chemical tests were performed by gas chromatographic and chemical methods. Mean margin of error constituted 5-10% in analyses making three parallel readings of traces of compounds.

We examined the nature of effects of PTOB formed at different temperatures of fluoroplastic F-40 breakdown. We counted the number of animals that died, which was compared to the level of polymer heating and concentrations of gas emissions. We began the tests at high polymer heating temperatures (500 → 450 → 400 → 350 → 300°C), when signs of poisoning are the most distinct. The lethal poisoning effects were tested on mongrel white mice and severity of poisoning, on mice and rats. Since the combustion products of polymers of this group affect primarily the central nervous system, liver function, hematopoiesis, and they also cause circulatory disturbances in organs, we assessed the dynamics of the animals' weight during the experiment, the orienting response (according to rodent burrow reflex), composition of formed blood elements (blood formula), total lipid content of hepatic tissue, triglyceride levels of blood serum, carboxyhemoglobin of whole blood, pathomorphological and histochemical changes in the viscera. The animals were examined before and immediately after breakfast, then at different stages of a 2-week recovery period.

The obtained data were submitted to statistical processing with evaluation of reliability of differences using Student's criterion. Differences were

considered reliable if the level of significance did not exceed 0.05 ($P \leq 0.05$) with at least 10 cases involved.

Results and Discussion

In the course of thermal breakdown, a significant amount of volatile substances was emitted from fluoroplastic F-40. Heating to 500°C led to formation of a gas and aerosol complex, in which such toxic compounds were demonstrable as carbon monoxide and dioxide, hydrogen fluoride, formaldehyde, volatile organic compounds in concentrations of 11,700, 20,000, 44.2, 24.7 and 3960 mg/m^3, respectively. Inhalation of these PTOB for 10 min elicited 100% death of mice. From the first minutes of inhalation, the animals were restless, then they presented convulsive twitching of the limbs, which was indicative of the neuroparalytic effect of the gas-aerosol complex. As a rule, the animals died quickly. Necropsy failed to reveal macroscopically visible disturbances in the viscera, which was also indicative of the neuroparalytic nature of poisoning.

Heating the sample to 450°C led to appearance of the same volatile constituents in the air as at 500°C, but in lower concentrations: 21.1, 22.5, 3.9, 48.5, 1760 and 400 mg/m^3 for hydrogen fluoride, organofluorine compounds, formaldehyde, carbon monoxide and dioxide, volatile organic compounds, respectively. It must be noted that, although the levels of volatile organic compounds in PTOB did drop, as compared to exposure of the polymer to 500°C, they were still high. Inhalation of PTOB at this temperature led to death of 90% of the mice. There was prevalence of symptoms of neuroparalytic and irritant effects. In a mouse that survived PTOB poisoning, breathing remained heavy for 2-3 h after exposure, and each respiratory act was associated with considerable excursion of the rib cage. Pathomorphological examination of this animal 4 h after exposure revealed circulatory disturbances in the lungs, heart and parenchymatous organs. The lung presented edema of the tissue.

Thus, the signs of poisoning observed in animals who inhaled gas emissions from fluoroplastic F-40 were indicative of presence of intoxication by fluorine derivatives of hydrocarbons, while the effect of irritation of lung tissue showed that hydrogen fluoride was present in the gas emissions.

At 400°C temperature, hydrogen fluoride, organofluorine and volatile organic compounds, carbon monoxide and formaldehyde were emitted from the fluoroplastic in concentrations of 11.8, 44.6, 24.9, 17.7 and 2.5 mg/m^3, respectively. We were impressed by the low concentration of carbon monoxide in the gas emissions (considerably lower than at 450°C). In this test, we failed to observe animal deaths after inhalation of PTOB emitted from the fluoroplastic when heated to 400°C, either during exposure or in the next 2-week observation period. However, after this exposure, the mice were inactive and their fur was ruffled.

When evaluating the toxicity of PTOB, not only data about temperatures at which the polymer is broken down, which elicit lethal effects in animals, are necessary, but also information about heating temperatures at which disturbances are observed in different functional systems of the body.

At temperatures of 300 and 350°C, no hydrogen fluoride or carbon dioxide were demonstrable among the gas emission products, while the concentrations of volatile organic compounds was on the same level when F-40 was heated to 350°C as in gas emissions of the fluoroplastic heated to 400°C.

Inhalation by mice and rats of products of thermal-oxidative destruction of fluoroplastic, when it was heated to 350°C, did not elicit changes in behavior or appearance of the animals. However, in the 1st week after inhalation, rats showed a decrease in weight gain (Figure 1). In addition, they presented a reliable 30% ($P<0.05$) decline of the orienting response, which was indicative of functional depression of the central nervous system (CNS).

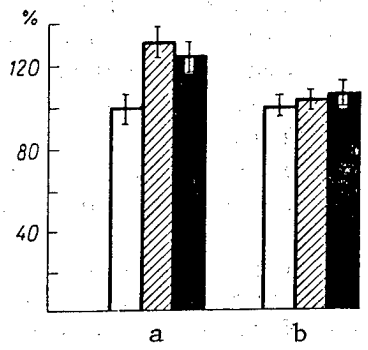


Figure 1.
Diagram of weight gain by white rats after inhalation of fluoroplastic F-40 PTOB (% of baseline)
Here and in Figure 2:
a, b) polymer heated to 300 and 350°C, respectively.
White bars--baseline data, striped and black--1 and 2 weeks after inhalation, respectively

At the end of the 1st and 2d weeks after inhalation, peripheral blood presented a reliable decrease in number of segmented neutrophils by a mean of 19% ($P<0.05$) and increase in lymphocytes, from 62 to 72% ($P<0.05$). This can apparently be interpreted as the body's nonspecific reaction to poisoning. We also demonstrated an increase in rat blood triglyceride content on the 3d day after inhalation ($P<0.01$) (Figure 2). On the 10th day, the difference in this parameter in experimental animals, as compared to the control, was statistically unreliable. We failed to demonstrate statistically significant changes in total lipid content of the rat liver on the 10th day of the aftereffect period. However, the 145% increase ($P<0.1$) in their levels (as compared to baseline) may be indicative of early stages of fatty degeneration of the liver as a result of the effects of the toxic agents.

Inhalation of products of gas emissions of F-40 heated to 350°C did not raise the level of blood carboxyhemoglobin, which is apparently attributable to the low level of carbon monoxide (5.5 mg/m^3) in the atmosphere of the chamber.

We determined the weight indexes of different internal rat organs on the 14th day after inhalation, and examined their microstructure. Weight indexes of the lungs, kidneys, spleen and adrenals were analogous to those of intact animals. However, inhalation elicited a reliable decline ($P<0.05$) in relative weight of the liver and, as shown by examination of histological preparations, this was due to uneven delivery of blood to this organ's vessels. Lung tissue showed an increase in number of eosinophils and lymphoid cells, which was indicative of possibility of sensitization of tissue.

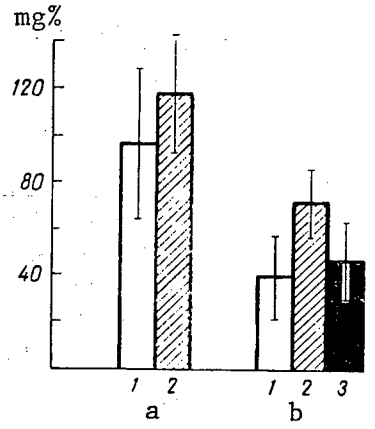


Figure 2.
Blood triglyceride levels in rats after exposure to fluoroplastic F-40 PTOB
White bars--baseline data;
striped--3d day after exposure;
black--1 week after exposure

No emissions from the fluoroplastic were demonstrable when it was heated to 300°C. We also failed to detect changes in behavior or appearance of animals. The experimental and control groups of rats actively consumed feed and gained weight regularly (see Figure 1). No significant difference was demonstrated in functional state of the CNS in experimental animals, as compared to the baseline, although there was some variability of this parameter at different postinhalation times. Formed blood element count, levels of carboxyhemoglobin and triglycerides (see Figure 2) in blood, and relative weight of organs did not differ in experimental rats from the values for control animals.

Thus, a hazard of poisoning by products of thermal breakdown appears when the polymer is heated to at least 400°C.

The following toxic constituents were demonstrable in products emitted from the polymer based on tetrafluoroethylene at temperatures of 400°C or higher: hydrogen fluoride, organofluorine compounds, carbon monoxide and formaldehyde. At these temperatures, the concentrations of toxic agents in PTOB were considerably higher than allowable levels in air.

Our findings enable us to maintain that toxicological evaluation of the atmosphere of closed environments, in the case of heating of fluoroplastics, must be made with consideration of concentrations of fluorine compounds and, in particular, hydrogen fluoride content, since acute poisoning by products of thermal-oxidative breakdown of fluoroplastics is due to presence of fluorine compounds. Heating of this group of polymers to 300°C may be considered allowable according to sanitary and hygienic parameters in the case of brief exposure time.

BIBLIOGRAPHY

1. Blagodarnaya, O. A., GIG. TRUDA, 1973, No 5, pp 25-29.

2. Gorban, G. M., Bizin, Yu. P., Sopikov, N. F. et al., in "Vsesoyuznaya konf. po kosmicheskoy biologii i aviakosmicheskoy meditsine. 6-ya. Tezisy dokladov" [Summaries of Papers Delivered at 6th All-Union Conference on Space Biology and Aerospace Medicine], Moscow--Kaluga, 1979, Pt 2, pp 108-110.

3. Ilichkin, V. S. and Ivanova, L. V., GIG. TRUDA, 1978, No 4, pp 40-44.

4. Kolchina, Ye. V., Yablochkin, V. D., Shchirskaya, V. A. et al., in "Aktualnyye voprosy kosmicheskoy biologii i meditsiny" [Pressing Problems of Space Biology and Medicine], Moscow, 1971, pp 166-169.

5. Korshak, V. V., "Termostoykiye polimery" [Heat-Stable Polymers], Moscow, 1969.

6. Khamidullin, R. S., Petrova, G. A., Karpova, G. Ya. et al., GIG. I SAN., 1977, No 1, pp 38-41.

7. Harris, D. K., BRIT. J. INDUSTR. MED., 1959, Vol 16, p 221.

8. Polakoff, P. H., Heinachiro, A. and Reisuke, S., AMER. INDUSTR. HYG. ASS. J., 1974, Vol 35, pp 99-106.

UDC: 629.78:574.685]:631.234

GREENHOUSES WITH CURVILINEAR PLANTING SURFACE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 12 Jun 84) pp 77-80

[Article by Yu. A. Berkovich, V. A. Korbut and V. I. Pavlovskiy]

[English abstract from source] The laws of light distribution in plants sown on the flat plane, spherical or cylindrical surfaces were investigated. in microgravity where the plants are arranged radially the level of illumination of lower leaf strata is higher on curvilinear than on flat surfaces. This is due to the following: as the plants grow they get separated; also, the concentration of the light flux increases with depth of plants on the curvilinear surfaces. In view of this, a space greenhouse is suggested, the design of which provides high productivity per unit volume and per unit energy of the incident flux of photosynthetically active radiation.

[Text] Research greenhouses for higher plants have gained broad use in recent years in biological experiments conducted in space [1, 2]. It is also planned to make future use of higher plants aboard spacecraft as a source of vegetable food and to improve the psychological comfort of crews during long-term missions [3, 7]. The designs for space greenhouses existing to date are in essence the same as the vegetation chambers used on earth, and differ from the latter merely in that the system of root feeding of the plants was updated for weightless conditions.

We propose here a new class of designs for vegetation units for plant growing in space, which makes it possible to take advantage of absence of gravity to improve distirbution of light in plants.

It is known that the productivity of plantations over a wide range of growing conditions is proportionate to irradiation of the plants by a flux of photosynthetically active radiation (PAR). The coefficient of proportionality of this function includes the cofactor of the product of two characteristics of sowing averaged in time, namely the coefficient of plant absorption of PAR flux and coefficient of utilization by plants of PAR flux for photosynthesis. Thus, plant productivity depends significantly on the properties of the plantation as an optical system, which are usually

characterized by distribution of light in depth of the plant layer. In order to obtain high values for efficiency of the plants as PAR recipient, the following conditions must be met: 1) PAR to the plants must be absorbed virtually entirely by them; 2) irradiation of photosynthetic organs in the very lowest strata of the plantation must exceed the light compensating point, i.e., the PAR energy flux density at which intensity of plant photosynthesis equals intensity of their respiration.

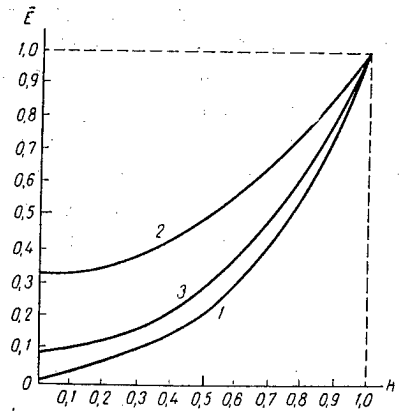
There are difficulties involved in meeting the above conditions for a crop of plants of the same age on a plane, due to the manyfold increase in photosynthetic surface of plants in ontogenesis. With the sowing density used for such plantations, the leaf index for young plants does not usually exceed 1, which is indicative of failure to abide by the first condition; however, at the end of vegetation, the leaf index increases to 10 or more, as a result of which the second condition fails to be met. In order to provide optimum optical properites in a plant crop on a plane throughout the vegetation period, a method was proposed of separating the plants as the leaf surface grows [6]. However, to use this method on a flat sowing surface the plants have to be moved, which requires additional equipment and complicates appreciably the technology of raising them.

Absence of gravity during a spaceflight offers the opportunity of forming crops on a curvilinear sowing surface, for example, spherical or cylindrical, with the plant stalks situated on normals to this surface. While stalks are vertical on the ground, regardless of shape of sowing surface, due to a geotropic reaction, in weightlessness it has been observed, in particular in [4], that the direction of the stems can be determined by phototaxis. Consequently, by specifying a light field with different spatial characteristics in weightlessness by means of light engineering devices, we are able to obtain crops with stems going in different directions in space. If, for example, we were to place an external uniformly illuminating light source of the same shape concentrically to the spherical or cylindrical sowing surface, in the absence of gravity the plant stems will go along the continuations of the radii of the sowing surface. In such plantations, shadowing of the lower leaves of plants would be diminished and there would be improved use of light energy for photosynthesis. Indeed, let us compare the laws of light distribution for two variants of plantations (in our case, we used wheat plants): 1) for a crop with vertical stalks on a plane and 2) for a crop with radial arrangement of stalks on a sphere with radius r. For the sake of convience of comparison, let us consider that the same energy W_o in the form of PAR flux is directed from the outside to each of the plantations, and that it is uniformly distributed over the light-receiving surface of the crop; and the area of this surface measured on the level of plant apices will be considered to be S_o in both instances. Let us also assume that each crop consists of the same number of plants of the same age with the same mean biometric parameters. According to these assumptions, the distribution of photosynthetic organs of the plants with respect to height of crop will be the same in both cases.

As we know [5], distribution of light in dense plantations, i.e., those in which the leaf index exceeds 1, can be approximately described by an exponential law of the following appearance:

$$\bar{E} = A \exp(B\bar{H}), \qquad (1)$$

where $\bar{E} = \frac{E}{E_0}$ is normalized irradiation of plant layer at height H from sowing surface, E_0 is plant irradiation at the level of their apices, $\bar{H} = \frac{H}{H_0}$ is normalized distance between plant layer and sowing surface, H_0 is mean height of plants in crop; A and B are coefficients.



Curves of distribution of light flux over height of plantations
1-3) plantations on plane, sphere and circular cylinder, respectively

The experimental curve of distribution of light over the height of the wheat crop on a plane with H_0 = 0.75 m and with a mean leaf index of 10:18 is illustrated in the Figure by curve *1*.

According to law (1), the crop layers with the same thickness and same distribution of photosynthetic organs over their height absorb the same share of incident light flux W_0. Consequently, it can be considered that total energy of PAR flux penetrating in the crop to height $\bar{H}$ will be the same in cases of flat and spherical sowing surface; hence:

$$W_c(\bar{H}) = W_п(\bar{H}), \qquad (2)$$

where $W_c(\bar{H})$ and $W_П(\bar{H})$ are total energy of PAR flux in plant layer at height $\bar{H}$ for spherical and flat plantations, respectively.

Irradiation in a plant layer on a spherical surface at height H equals:

$$E_c = \frac{W_c(H)}{S_c(H)} = \frac{W_c(H)}{4\pi(r+H)^2}. \qquad (3)$$

Similarly, irradiation in a layer at height H of a flat surface will be:

$$E_п = \frac{W_п(H)}{S_0} = \frac{W_c(H)}{4\pi(r+H_0)^2}. \qquad (4)$$

Turning to normalized variables, let us write down, from equations (2), (3) and (4), the relationship between the laws of light distribution in the two plant sowing variants we are comparing:

$$\bar{E}_c(\bar{H}) = \bar{E}_п(\bar{H})\left(\frac{1+\bar{r}}{\bar{H}+\bar{r}}\right)^2, \qquad (5)$$

where $\bar{r} = \frac{r}{H_0}$.

Curve *2* in the Figure illustrates light distribution in a spherical plantation of wheat with the following parameters: r = 0.25 m, H_0 = 0.75 m.

If we conduct an analysis of light distribution in two comparable plantations similar to the one described above--with flat and cylindrical sowing surfaces--and considering a circumference with radius R as the directrix for the cylindrical surface, we shall obtain the following equation:

$$\overline{E}_{II}(\overline{H}) = \overline{E}_{II}(\overline{H}) \cdot \frac{1+\overline{R}}{\overline{H}+\overline{R}}, \qquad (6)$$

where $\overline{R} = \frac{R}{H_0}$.

In this equation, $\overline{E}_{II}(\overline{H})$ is the normalized irradiation in a plant layer of a cylindrical plantation at height $\overline{H}$ from the sowing surface.

The law of distribution of light in a cylindrical sowing surface with R = 0.25 and H_0 = 0.75 m is illustrated in the Figure by curve *3*.

Let us mention that irradiation of plants in the lower tiers of the plantations with curved sowing surfaces could be considerably higher than in flat-sown crops. From this, it can be concluded that it becomes possible to augment specific yield of biomass per unit volume occupied by the plantation and per unit energy of incident PAR flux due to activation of photosynthesis in lower leaves in nurseries with curved sowing surface. The main causes of more uniform distribution of light in such plantations are: self-spreading of plant stalks as they grow and concentration of luminous energy penetrating on the surfaces of the plant strata, which diminish in depth. It is expressly for these reasons that curve *2* of distribution of light in a spherical plantation, where the stalks spread over all three coordinates of three-dimensional space is situated higher in the Figure than curve *3*, which corresponds to cylindrical sowing with two-dimensional spreading of stalks.

We confirmed the feasibility of raising crops with radial arrangement of stalks in a ground-based experiment with wheat plants that were raised in a device with spherical sowing surface that revolved about three mutually perpendicular axes at mean velocities of 2 r/day, which made it possible to neutralize, in part, the effect of the plants' geotrophic reaction. However, a complete experimental verification of the above-described functions can be made only in weightlessness.

In conclusion, it should be noted that the use of curved sowing surfaces makes it possible to propose some rather compact and technologically effective designs for conveyer greenhouses for space life-support systems. On the whole, the results of the preliminary studies have demonstrated a number of advantages and confirmed the feasibility of space greenhouses with curved sowing surface.

BIBLIOGRAPHY

1. Ilin, Ye. A. and Parfenov, G. P., eds., "Biologicheskiye issledovaniya na biosputnikakh 'Kosmos'" [Biological Studies Aboard Cosmos Biosatellites], Moscow, 1979, pp 149-170.

2. Mashinskiy, A. L. and Nechitaylo, G. A., TEKHNIKA MOLODEZHI, 1983, No 4, pp 4-9.

3. Morozov, G. I., "Problemy kosmicheskoy biologii" [Problems of Space Biology], Vol 36, Moscow, 1977.

4. Platonova, R. N. and Lyubchenko, R. Yu., in "Kosmicheskaya biologiya i aviakosmicheskaya meditsina" [Space Biology and Aerospace Medicine], Moscow--Kaluga, 1982, Pt 2, pp 145-146.

5. Ross, Yu. K., "Radiatsionnyy rezhim i arkhitektonika rastitelnogo pokrova" [Radiation Conditions and Architechtonics of Vegetation Cover], Leningrad, 1975, p 286.

6. Chuchkin, V. G., PRIRODA, 1967, No 10, pp 68-69.

7. Shepelev, Ye. Ya., in "Osnovy kosmicheskoy biologii i meditsiny" [Bases of Space Biology and Medicine], eds. O. G. Gazenko and M. Kalvin, Moscow, 1975, Vol 3, pp 277-313.

UDC: 629.78:612.825.8-08

DEVICE FOR COMBINED STUDY OF VISUAL TRACKING AND VERBAL ACTIVITY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 10 Jul 84) pp 80-82

[Article by B. A. Karpov and A. I. Pudov]

[Text] The diverse forms of industrial and research work often require that man combine intensive visual tracking with verbal activity. A pilot or cosmonaut may be compelled to keep attentive watch over relatively mobile reference points, targets and other objects and, at the same time, hold responsible conversations, receive or give orders, receive important information orally, etc. An operator working in a system of detection and accompaniment of moving targets functions under similar conditions. This type of activity leads to the necessity of altering the direction of attention, which can be done voluntarily or involuntarily, depending on the functional significance of tracking and verbal communication. The redistribution of attention to the area of verbal activity may have a marked effect on the quality of visual tracking, leading to adverse end results of activity--insufficiently accurate visual spatial estimates, delayed and erroneous control movements, etc. Consequently, experimental investigation of interaction of automated visual-motor responses with concomitant verbal activity acquires substantial practical importance. Already in the course of vocational screening of certain specialists, it is desirable to determine how and to what extent a verbal load (particularly when it is ongoing and emotionally significant) affects visual tracking by a subject. Such data could also enable us to detect verbal disturbances that are not very noticeable in conventional forms of examinations. Moreover, it is of practical importance to know which type of verbal load has the greatest effect on visual tracking. Of course, it is equally important to have information about the effect of visual tracking on characteristics and effectiveness of verbal communications of an observer.

It is necessary to make synchronous records of the subject's eye movements, his speech as well as speech addressed to him for a quantitative evaluation of tracking distinctions associated with a verbal load. An experimental device designed to solve this problem should meet the following conditions: 1) eye movements must be recorded by a rather sensitive method, so that all elements of functional significance to tracking of eye movements in the macro- and micro-range (with the exception of tremor) are distinctly recorded. The high resolution of the recording method must make it possible to examine tracking of targets that are moving over comparatively short distances, since it is

expressly such targets that sometimes play an important part in an operator's decision making; 2) the test signals delivered for tracking must be few in number and standard, typical. At the same time, the set of signals must yield information about both the status of the system of smooth tracking and status of the system of saccadic tracking; 3) the tracing obtained as a result of the examination must provide a clear idea about the oculomotor and verbal activity of the subject, as well as the speech of individuals with whom he converses.

A device for simultaneous and combined recording of two processes in graphic form--eye movements when tracking visual stimuli and concomitant conversation--was developed and is being used in the laboratory of voice and speech pathology of the Leningrad Scientific Research Institute of the Eye, Throat and Nose.

The device contains the following functional units: system for recording eye movements, system for acoustic and visual recording of verbal signals, system of presentation and recording test signals for tracking. The structural diagram of this device is illustrated in Figure 1.

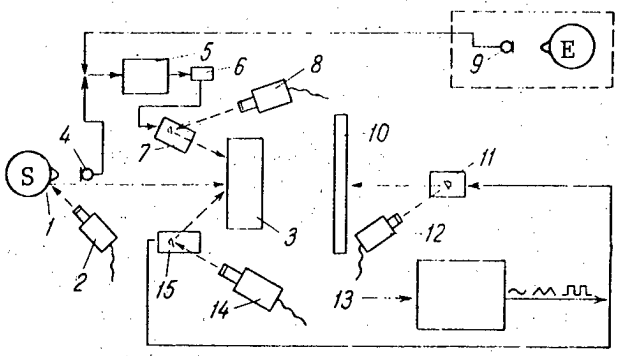


Figure 1.
Diagram of device for combined recording of visual tracking and verbal activity. Explained in the text

A photographic optic method developed by A. L. Yarbus [1] is used to record the subject's (S) eye movements. After anesthetizing the dominant eye with 0.5% dicaine solution, a suction cup *1* is applied on the sclera, and there is a mirror on this cup. A beam of light is aimed from slit lamp *2* to this mirror and, being reflected, the light penetrates into the slit of photokymograph *3* where the horizontal component of eye movements is recorded on moving photographic paper.

The speech of the subject and experimenter (E) is recorded as follows. The subject's speech is recorded with microphone *4* on tape recorder *5*. After detection with a full-wave rectifier and spectrum restriction with low-frequency filter *6*, the verbal signal amplified in the tape recorder goes to galvanometer *7*, the mirror of which is illuminated by slit lamp *8*. The light beam reflected by the mirror penetrates into the slit of the photokymograph and forms a "sonic path." The mirror of galvanometer *7* turns in accordance with intensity of the signal coming from microphone *4*, and this causes displacement of the beam aimed at the slit of photokymograph *3*. The subject's eye movements and low-frequency envelope of the verbal signal are recorded synchronously on photographic paper.

The speech of the experimenter communicating with the subject (instructions, commands, etc.) is recorded by the same system, but with use of additional microphone *9*. If the experimental conditions require simultaneous but separate recording of the subject's and experimenter's speech, an additional line is installed to record the experimenter's speech.

Test visual stimuli, the movement of which the subject tracks, are formed as follows. At a distance of about 100 cm in front of the subject a semi-opaque screen *10* (frosted glass) is placed. Galvanometer *11* is behind the screen. From lamp *12*, which has a spot diaphragm, aims a beam of light to the mirror [of the galvanometer]. The diaphragm and optical system of the lamp provide for a visible dimension of the focused beam of light on screen *10* on the order of 6-8'. In such a case, the stimulus is commensurate in area with the size of the receptive field of the center of the retina and is perceived as a spot of light, which precludes the eyes from jumping within the area of the target. This is an important item, since errors are possible in gaging the position of the glance due to saccadic movements from one edge of the target to another when presenting large targets.

Test movements of the visual stimulus are provided by a low-frequency wave generator *13*. Depending on the purpose of the test, one can use pendulum (sinusoidal) and other types of movements of the tracked target. Choice of amplitude and frequency of oscillations also depends on the specific purpose. Precise comparison of amplitude and frequency characteristics of the moving target and tracking eye movements is made by the subject because the signal controlling target movement is also delivered to galvanometer *15*, the mirror of which is illuminated by slit lamp *14*, while the reflected beam of light reproduces on the photographic paper all movements of the target. As a result, there is a synchronous tracing of movements of the tracked visual stimulus, tracking eye movements of the subject and low-frequency envelope of the verbal signal on the same oscillogram.

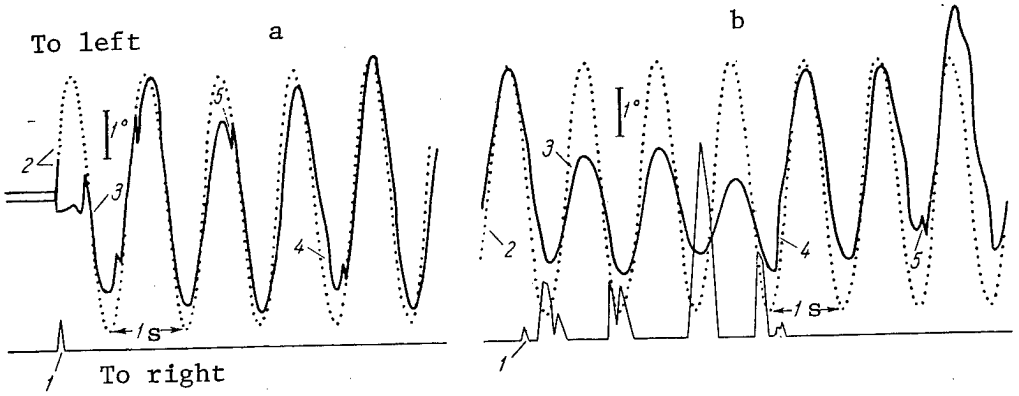


Figure 2. Combined tracing of tracking eye movements (a) and speech (b)
1) "sonic path" with mark for start of movement of target (a) and subject's speech recording
2) tracking of target movements: amplitude of oscillations 5.3°, frequency 1.0 Hz
3) smooth tracking eye movements
4) saccadic components of tracking in direction of movement of target
5) same in opposite direction

Change in characteristics of eye movements, which corresponds with the subject's verbal activity, can be clearly seen in section (b) from the 2d to 4th tracking period.

Figure 2 illustrates tracings made in the course of one of the studies. At first, the subject fixed his glance on a stationary target in the center of the screen (see Figure 2a). Then the target began to swing in pendulum fashion in the frontal plane, in relation to the subject's face, at a frequency of 1.0 Hz and amplitude of 5.3°. The start of oscillation of the target is marked on the sonic path *1*. The trajectory of movement of target *2* is shown by the dotted line, with the exception of the very beginning, when the target jumped when it was turned on. After a certain latency period, the subjects began to track the target ("baseline tracking"). The tracing shows the smooth tracking eye movements *3* and saccadic movements both in the direction of movement of target *4* and in the opposite direction *5*. After recording the "baseline" tracking, the subject was presented with a verbal task. Figure 2b illustrates a section of the tracing of tracking eye movements during the period of motor verbal activity (tracing on "verbal path") and upon ceasing to speak. A comparison of the tracings in Figure 2a and b shows that the verbal load altered tracking appreciably, mainly by reducing the sweep of tracking eye movements. After ceasing to talk, the tracking movements showed close to baseline characteristics.

Thus, the synchronous recording of tracking eye movements combined with the tracking of target movements and verbal signal enable us to assess quantitatively all of the relevant characteristics of tracking eye movements and to compare them to the nature of the subject's verbal activity. The change in patterns of movement of tracked target (linear reversals, meandering, etc.), frequency and nature of the verbal load enable us to gain more detailed information about interaction between the visual tracking system and speech system. By recording speech on tape, we can compare any segment of the signal envelop on photographic paper to a concrete lexic, meaningful and emotional-intonational characteristic of conversation. Thus, the distinctions of oculomotor activity can, in turn, be compared to various characteristics of speech. On the basis of some experience, we can mention that the tracing of eye movements with resolution level at which 1 mm of the tracing corresponds to 2-3' displacement of the eye is the most informative. Resolution on the time axis must conform to the frequency of the tracked signal: at frequencies close to 1.0 Hz, it is desirable for 1 mm to contain a segment of no more than 30-50 ms.

The device and method of combined analysis of tracking and verbal activity can be used in research in the field of general and engineering psychology, physiology and pathology of control of movements, linguistics, as well as in the study of speech disorders.

BIBLIOGRAPHY

1. Yarbus, A. L., "Rol dvizheniy glaz v protsesse zreniya" [Role of Eye Movements in the Vision Process], Moscow, 1965.

UDC: 629.78.048.7:612.591

METHODOLOGICAL PROBLEMS RELATED TO GROUND-BASED TESTING OF TEMPERATURE-CONTROL SYSTEM FOR MANNED SPACECRAFT

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 14 Aug 84) pp 82-83

[Article by L. B. Strogonova]

[Text] The temperature-control system (TCS) of manned spacecraft is one of the chief elements of the life-support system that affect the structural features of the craft as a whole. Not only reliable and proper operation of craft instruments, equipment, scientific apparatus, but work capacity of crew members depend on operation of this system [2].

Analysis of data in the literature [1] shows that mathematical modeling with consideration of possible identification of parameters of the mathematical model should find broad application in the field of experimental development of TCS.

In practical design of TCS, mathematical models have gained wide use. However, the reliability of results obtained with them requires experimental confirmation, since a number of assumptions must be made in building mathematical models. The combined use of mathematical modeling methods, decomposition and identification with conventional methods of experimental ground-based development of TCS improves the quality of ground-based heat tests and reliability of their results. The choice of type of mathematical model, as well as the concrete specifications imposed on it, are determined by the method of ground-based testing, their purpose and tasks. It is known, that the operation of TCS is characterized by existence of nonstationary heat-transfer processes in virtually all elements of the system. In cases where the environmental properties have variable coordinates, processes that take place in the system are described by a system of differential equations in partial derivatives with variable coefficients. The precise solution to such systems of equations involves some difficulties, and analytically one can merely solve a limited class of problems, and the obtained functions are so complex that they cannot be used in engineering practice. Concrete assumptions, which are considered together with questions of reliability of results, make it possible to reduce the system of equations in partial derivatives to a system of common differential equations. There are different types of mathematical models based on systems of common differential equations: model characterizing heat-transfer elements with concentrated parameters that consider the distribution of

parameters; models that occupy an intermediate place; a new type of mathematical models--locally generalized. At the stage of conducting heat tests on the ground, a system of common differential equations with concentrated parameters is the most suitable type of mathematical model of TCS of spacecraft. The process of identifying the parameters of the mathematical model according to results of filtration of experimental data obtained in the course of a ground-based experiment makes it possible to simplify the adopted mathematical model of the system and render it adequate to the conditions in question. Estimates show that the margin of error in the results of mathematical modeling does not exceed a mean of 8-10% in this case. Use of mathematical modeling also makes it possible to conduct model studies for modes of spacecraft TCS operation that can be classified as emergency modes.

Optimum combination of mathematical modeling and traditional methods of ground-based experimental development permits forecasting the behavior of a system (in this case, the spacecraft TCS) in emergency situations, examining the possible consequences of malfunction in different elements without damaging the ground-based testing bench and assessing stability of the system with change in its different characteristics.

BIBLIOGRAPHY

1. Malozemov, V. V., "Teplovoy rezhim kosmicheskikh apparatov" [Temperature Conditions in Spacecraft], Moscow, 1980.

2. Stroganova, L. B. and Glushko, A. A., in "Kosmicheskaya biologiya i aviakosmicheskaya meditsina" [Space Biology and Aerospace Medicine], Moscow--Kaluga, 1982, Pt 2, pp 197-198.

BRIEF REPORTS

UDC: 629.78:612.1-08

EFFECT OF ACTIVE ANTIORTHOSTATIC CONDITIONING ON TOLERANCE TO CRANIAL REDISTRIBUTION OF BLOOD

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 13 Dec 84) pp 83-85

[Article by A. F. Zavadovskiy, M. M. Korotayev, S. V. Kopanev, I. A. Plyasova-Bakunina and Yu. N. Vavakin]

[Text] At the present time, antiorthostatic position of the body is used extensively in aerospace medicine as a model for investigation of reactions of the cardiovascular system to gravity-caused redistribution of blood. In particular, one can predict, to some extent, tolerance of the circulatory system to weightlessness, particularly in the acute period of adaptation, by means of the antiorthostatic test at angles of -15 and -30° [2, 5, 11, 12].

A distinction is made between active and passive orthostatic tests. In the active form, the subject assumes an antiorthostatic position by himself and voluntary muscular tension is mandatory; in the passive form, the position is usually obtained by means of a turntable. Under these conditions one observes muscular relaxation [4].

It was observed that adaptive reactions develop in the body upon repeated exposure to both active [3] and passive [1] orthostatic tests.

Our objective here was to investigate the flexibility of regulatory mechanisms of the cardiovascular system and possibility of enhancing the body's tolerance to gravity-related redistribution of blood by using active antiorthostatic tests.

Methods

A total of 10 essentially healthy men 29-40 years of age participated in the study; they remained on their customary schedule of work, leisure and diet. They were submitted to active antiorthostatic tests 3 times a week, which were combined alternately with special exercises and general physical exercises.

Tolerance to cranial redistribution of blood was evaluated with the antiorthostatic test on a turntable with a tilt angle of -30° for 20 min, before, after 10 and 25 exercise sessions. During the test, we examined central and

Parameters of regional circulation in the brain, lungs, eye and legs during antiorthostatic tests before and after antiorthostatic conditioning

Time of exam.	Body position	Minute of study	Frontomastoid lead				Bimastoid lead				RI in right lung, Ω	Total delivery of blood, mℓ		DPCRA, mm Hg
			RI, Ω	DCI, %	DSI, %	α/t, %	RI, Ω	DCI, %	DSI, %	α/t, %		head	legs	
Before training	BL (0°)	1	0,121±0,024	61,2	66,4	12,1	0,096±0,016	74,6	78,8	15,1	0,221±0,009	242±28	1484,4±149	45±2,4
	—30°	20	0,217±0,018	32,4	33,1	18,4	0,149±0,021	38,4	42,6	21,8	0,291±0,014	256,3±24,5	1393,8±141	66±3,1
			0,204±0,019	50,8	51,4	18,2	0,138±0,017	36,6	39,1	22,1	0,282±0,012	283±25	1324,8±137	69±3,5
	Δ		0,083	—10,4	—15,0	6,1	0,042	—38,0	—39,7	7,0	0,061	41	—159,6	24
After 10 training sessions	BL (0°)	1	0,138±0,020	54,8	56,1	14,1	0,099±0,009	60,3	62,4	16,2	0,212±0,005	244,8±21	1548,3±83	
	—30°	20	0,208±0,014	58,4	60,0	26,8	0,151±0,019	64,7	66,6	30,2	0,250±0,010	254,5±22,6	1487,5±81	
			0,173±0,026	61,4	62,8	26,4	0,119±0,021	63,8	66,8	31,4	0,241±0,008	272,3±24,7	1401,4±83	
	Δ		0,035	6,6	6,7	12,3	0,020	3,5	4,4	11,2	0,029	27,5	—146,9	
After 25 train. sessions	BL (0°)	1	0,120±0,017	49,8	52,1	13,8	0,113±0,014	52,1	53,4	15,8	0,255±0,007	259,7±10,3	1447,1±132	41±3,5
	—30°	20	0,185±0,021	67,8	69,9	28,1	0,147±0,019	60,1	62,8	31,9	0,279±0,011	267,2±12,1	1392,7±126	50±2,2
			0,148±0,014	78,1	80,4	27,7	0,130±0,016	71,2	63,9	31,6	0,277±0,008	281±13,8	1339,5±125	53±1,8
	Δ		0,028	28,3	28,3	13,9	0,017	19,1	10,5	15,8	0,022	21,3	—107,6	12

Key: BL) baseline

regional hemodynamics of the brain and both of its reservoirs, as well as of the lung and eye, and we determined total delivery of blood to the head and legs. For this purpose, we recorded the rheoencephalogram (REG) in the frontomastoidal and bimastoidal leads, rheogram (RG) of the right lung, electrocardiogram in lead II and measured arterial pressure (BP) before the test (horizontal position), in the 1st, 5th, 10th, 15th, 20th min in antiorthostatic position and in the 1st, 5th and 10th min after it (in horizontal position). The RG was analyzed by the conventional method with determination of parameter of pulsed delivery of blood, tonus and elasticity of vessels of large caliber, small arteries and arteiroles, veins and venules [10]. Total delivery of blood to the head and leg regions was also measured by rheography [6]. Regional hemodynamics of the eye were studied by determining diastolic pressure in the central retinal artery (DPCRA) by the method of ophthalmodynamometry. We found the region of dissemination of altered coloration of the integument, measuring the distance from it to the top of the umbilical ring.

Results and Discussion

Analysis of answers of the subjects to a questionnaire revealed that they endured the antiorthostatic test subjectively better after the training sessions: less rush of blood to the head, disappearance of sensation of bulging of eyeballs, pulsation in the region of the neck and temples, nasal congestion, and the tilt angle was perceived as being smaller than it actually was.

The zone of dissemination of altered coloration of the integument in the upper part of the body decreased by 4.5-5 cm. No pathological changes whatsoever were demonstrable on the ECG during the tests. Frequency and

amplitude characteristics were in the range of variability of this age group. BP ranged from 110/70 to 130/80 mm Hg.

We observed considerably less increase in parameters of pulsed delivery of blood (rheographic index--RI) to vessels of the brain in both reservoirs tested and lung (see Table). Thus, while this parameter increased by 0.083 Ω in the frontomastoid lead, by 0.042 Ω in the bimastoid lead and by 0.061 Ω for the lung in the 20th min of antiorthostatic position before conditioning, after the training it increased by only 0.028, 0.017 and 0.022 Ω, respectively ($P<0.01$). We observed considerably less increase in total delivery of blood to the head, by only 21.3 mℓ as compared to 41 mℓ before conditioning. Total delivery of blood to the legs diminished by only 107.6 mℓ. Diastolic pressure increment in the central retinal artery decreased to one-half (from 24 to 12 mm Hg; $P<0.001$). The observed changes in regional hemodynamics of the head before conditioning occurred in the presence of insignificant increase in tonus of vessels of large and medium calibers (α/t increased by only 50%) and decrease in tonus of arterioles (DCI) and veins (DSI). Such a state of vascular tonus apparently led to distention and lengthening of the open capillary bed [9], total delivery of blood to vessels and sensation of blood rushing to the head, bulging of eyeballs, pulsation in the cervical region, etc.

Small arteries and arterioles of the brain, which have a thick muscular tunic [8, 12], play a major role in regulating cerebral blood flow. After conditioning, during antiorthostatic tests we observed significant increase in tonuse of arteries of all calibers and veins (α/t increased by 100%, DCI by 57% and DSI by 54%). Evidently, such tonus caused cerebral vessels to counteract plethora, limited arterial influx, reduced the capacity of the venous system and improved efflux of blood. Thus, the results of these tests demonstrated the effectiveness of using a cycle of active antiorthostatic conditioning as a means of enhancing the body's tolerance to redistribution of blood to the upper part of the body. As a result of its effect, the body develops adaptive and compensatory mechanisms which lead to an increase in cerebrovascular tonus and stabilization of cerebral circulation on a minimal level of intracranial plethora in response to gravity-related shifting of blood in a cranial direction.

BIBLIOGRAPHY

1. Alekseyev, D. A., Yarullin, Kh. Kh. and Vasilyeva, T. D., KOSMICHESKAYA BIOL., 1975, No 6, pp 55-61.

2. Vorobyev, Ye. I., Gazenko, O. G., Gurovskiy, N. N. et al., Ibid, 1976, No 5, pp 3-18.

3. Geykhman, K. L., "The Most Important Autonomic Changes in Man in Antiorthostatic Position," candidatorial dissertation in medical sciences, Perm, 1965.

4. Geykhman, K. L. and Mogendovich, M. R., KOSMICHESKAYA BIOL., 1977, No 3, pp 74-75.

5. Kalinchenko, V. V., Asyamolov, B. F. and Zhernavkov, A. F., Ibid, 1976, No 5, pp 18-23.

6. Maksimov, D. G., in "Aviakosmicheskaya meditsina" [Aerospace Medicine], Moscow--Kaluga, 1979, Pt 2, pp 55-56.

7. Sokolova, I. V. et al., ZHURN. NEVROPATOL. I PSIKHIATR., 1977, No 9, pp 1314-1321.

8. Folkow, B. and Neil, E., "Circulation," translated from English, Moscow, 1976.

9. Yarullin, Kh. Kh., Krupina, T. N. and Vasilyeva, T. D., KOSMICHESKAYA BIOL., 1972, No 4, pp 33-39.

10. Yarullin, Kh. Kh. and Vasilyeva, T. D., Ibid, 1977, No 3, pp 20-26.

11. Yarullin, Kh. Kh., Gornago, V. A., Vasilyeva, T. D. et al., Ibid, 1980, No 3, pp 48-53.

UDC: 612.398.192-06:612.275.1

SOME ASPECTS OF HUMAN AMINO ACID METABOLISM AT HIGH ALTITUDE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 10 Sep 84) pp 85-87

[Article by Yu. A. Sinyavskiy, T. F. Vlasova, M. S. Belakovskiy, Yu. A. Senkevich and B. I. Kim]

[Text] The problem of adaptation to altitude hypoxia has become particularly timely recently in view of the active economic development of mountainous regions and the need to perform difficult forms of physical and intellectual work at high altitudes. In addition, high-altitude climate is used extensively for prevention and treatment of cardiovascular and pulmonary pathology, as well as for holding training meets for representatives of different sports [2-4]. But stays at high altitudes and concomitant hypoxia lead to functional changes in different systems of the body, eliciting changes in energy, protein and amino acid metabolism, yet the latter has not been sufficiently investigated [1, 5, 7, 8, 16]. The sparse information about amino acid metabolism at high altitudes, which can be found in the literature, has not been adequately systematized and is not always unambiguous [1, 7, 8, 10, 16].

We undertook this study in order to assess amino acid metabolism as related to hypoxic conditions and physical exercise in top-ranking sport mountain climbers, who were candidates for an expedition to Mount Everest, at the time of their adaptation to high-altitude conditions and after an ascent to more than 4000 m above sea level.

Methods

Examination of 24 mountain climbers, prospective participants in an expedition up Mount Everest, was performed during the period of a training meet in the Tyan-Shan mountains (January) at an altitude of 1700 m above sea level. Venous blood was drawn on a fasting stomach 1 day before ascending Komsomol Peak (altitude 4376 m above sea level) and on the day after their return (adaptation period of 14 days, duration of ascent 1 day). We assayed plasma free amino acids by gas-liquid chromatography [13, 17]. Separation of amino acids in the form of n-butyl ether and N-trifluoroacetyl derivatives was performed on a Chrome-41 (CSSR) gas-liquid chromatograph.

Results and Discussion

The Table lists data on levels of free amino acids in blood plasma of mountain climbers before and after ascending to more than 4000 m above sea level. The amino acid pool of blood during the training period (14 days) was at the top of the physiological range and constituted 28.45 mg% (top limit of the norm is 28.96 mg%). However, there were deviations in concentrations of some amino acids in their blood. Thus, the cystine level was below the range of the physiological norm, whereas the concentration of ornithine was, on the contrary, above the physiological top range. Since there was a sufficient number of subjects to submit the results to statistical processing (24 people) and there was not much scatter of individual parameters, it can be assumed that the amino acid composition of the subjects' blood plasma was the physiological norm for the category of individuals whose occupation is related to constant physical and emotional loads under altitude hypoxia conditions. In addition, since blood samples were taken in the winter (January) and there were considerable seasonal fluctuations at high altitude, the obtained amino acid spectrum of blood is typical of the winter period. It should be noted that the mountain climbers were on a diet that was balanced in amino acid composition and all constituents during the period of our study.

Blood plasma free amino acid content in mountaineers before and after ascent (mg%)

Amino acid	Physiological norm	Before ascent (n = 24)	After ascent (n = 24)
Isoleucine	0,69—1,28 [6]	1,24±0,02	1,27±0,03
Leucine	1,42—2,30 [6]	2,15±0,08	2,21±0,06
Valine	2,37—3,71 [6]	2,50±0,01	2,61±0,07
Threonine	1,93±2,11 [15]	1,93±0,01	1,87±0,05
Serine	1,01±1,25 [6]	1,75±0,01	1,79±0,02
Methionine	0,50±0,58 [15]	0,52±0,01	0,46±0,02
Tyrosine	0,81—1,45 [6]	0,91±0,03	1,09±0,03
Phenylalanine	0,69—0,95 [6]	0,84±0,02	0,73±0,04
Cystine	0,69—0,77 [15]	0,53±0,03	0,44±0,05
Aspartic acid	0,01—0,07 [6]	0,36±0,01*	0,34±0,05
Glutamic acid	0,43—1,15 [6]	2,85±0,06**	2,61±0,07**
Proline	2,21—2,35 [15]	2,32±0,05	2,51±0,08
Glycine	2,23—2,41 [15]	2,31±0,05	2,41±0,05
Alanine	3,01—3,73 [6]	2,94±0,05	2,99±0,04
Lysine	2,51±3,02 [6]	2,94±0,06	3,00±0,03
Ornithine	0,62—0,80 [6]	1,75±0,04	1,78±0,02
Tryptophan	0,87—1,03 [15]	0,61—0,03	0,55±0,03
Totals	22,0—28,96 [6]	28,45	28,66

*With asparagine.
**With glutamine.

Comparative analysis of the data obtained after the ascent failed to demonstrate appreciable deviations in the blood free amino acid pool of the mountaineers, and the total amino acid content virtually failed to differ from values before the ascent (28.66 mg%). Cystine and ornithine concentrations also remained at the same level. Apparently, it was not by chance that there were no changes in amino acid pool of blood in this category of individuals, and it was attributable to the high degree of their physical

conditioning and identical adaptive reaction to altitude hypoxia. We cannot fail to mention the ambiguousness of data in the literature concerning studies of amino acid metabolism at high altitude. Thus, it is reported [17] that there was a decline of basic amino acid levels in blood after an ascent to 4200 mm [sic]. In addition, there are two contradictory reports of changes in amino acid pool of blood during the period of acclimation to high altitude: hyperaminoacidemia is reported in one [7] and, on the contrary, hypoaminoacidemia in the presence of elevated tyrosine level in the other, which was indicative of catabolic processes [1, 14]. Such divergent results could only be obtained due to differences in selecting the group of subjects, differences in their physical conditions and in adaptability. During periods of training meets at high altitude, sport mountain climbers are exposed to two factors simultaneously--hypoxia and physical loads. While the results of hypoxia in studies of amino acid metabolism are not always unequivocal, the effects of physical loads usually lead to certain changes in amino acid pool of blood, the severity of which depends on intensity of physical exercise. This is associated with elevation of blood alanine level, which reflects the intensity of gluconeogenetic processes in the liver and accumulation in blood of dicarboxylic amino acids, which result from catabolic processes in the body [9, 11, 12]. Since free amino acids are involved in numerous processes of interstitial metabolism, one should have expected changes in amino acid balance in the presence of hypoxia and physical loads. Such changes would have been the body's logical reaction and would be assessed as a compensatory reaction to hypoxia. Nevertheless, we failed to demonstrate appreciable changes in amino acid status of the subjects' blood. The stability of the blood amino acid pool is attributable to the fact that the group of subjects consisted of top-ranking sport mountain climbers accustomed to the combination of hypoxia and physical loads, as well as to ascents to more than 4000 m above sea level, which determined their synchronous response to altitude hypoxia.

Thus, the results we obtained here concerning the blood amino acid spectrum of subjects exposed to altitude hypoxia, during an acclimation period and after ascent to over 4000 m above sea level, indicate that the combination of hypoxia and physical loads does not affect the blood amino acid status of individuals with identical physical conditioning and identical adaptive reaction to high altitude. The data submitted in the course of our study on amino acid composition of blood plasma in sport mountain climbers during a winter training meet can be interpreted as the physiological norm for this group of individuals and the indicated season.

BIBLIOGRAPHY

1. Aydarkhanov, B. B., Sinyavskiy, Yu. A., Aldashev, A. A. and Kim, B. I., in "Teoreticheskiye i prakticheskiye aspekty izucheniya pitaniya cheloveka" [Theoretical and Practical Aspects of Studying Human Nutrition], Moscow, 1980, Vol 1, p 228.

2. Van Lir, E. and Stickney, J., "Hypoxia," translated from English, 1967.

3. Mirrakhimov, M. M., "Bolezni serdtsa i gory" [Heart Disease and the Mountains], Frunze, 1971.

4. Mirrakhimov, M. M., "Lecheniye vnutrennikh bolezney gornym klimatom" [Treatment of Internal Diseases With Mountain Climate], Leningrad, 1977.

5. Molchanova, O. P., VOPR. PITANIYA, 1937, No 6, pp 4-5.

6. Semenov, N. V., "Biokhimicheskiye komponenty i konstanty zhidkikh sred i tkaney cheloveka" [Biochemical Constituents and Constants of Human Body Fluids and Tissues], Moscow, 1971, pp 26-27.

7. Slotvitskiy, S. M. and Zuyev, B. N., TRUDY KIRG. MED. IN-TA, 1971, Vol 74, pp 279-284.

8. Aldashev, A. A., Sinyavsky, Yu. A. and Aidarkhakov, B. B., in "International Congress of Physiological Sciences, 28th. Proceedings," Budapest, 1980, p 809.

9. Brodan, V. and Kuhn, E., CSL. GASTROENT. VYZ., 1973, Vol 27, pp 280-283.

10. Consolazio, C. F., Matoush, K. R. and Johnson, H. L., AMER. J. CLIN. NUTR., 1968, Vol 21, pp 154-161.

11. Felig, P., Pozefsky, T. Marliss, E. and Cahill, G. F., SCIENCE, 1970, Vol 167, pp 1003-1006.

12. Felig, P., METABOLISM, 1973, Vol 22, pp 179-207.

13. Gerko, C., Kuo, K. and Zumualt, R., J. CHROMATOGR., 1971, Vol 57, pp 209-217.

14. Haralambie, G. and Berg, A., EUROP. J. APPL. PHYSIOL., 1976, Vol 36, pp 39-48.

15. Ushakov, A. S. and Vlasova, T. F., LIFE SCI. SPACE RES., 1976, Vol 14, pp 256-262.

16. Whitten, B. K., Haunon, J. P., Klain, G. J. and Chinn, K. S., METABOLISM, 1968, Vol 17, pp 360-365.

17. Zumwalt, R., Roach, D. and Gerke, C., J. CHROMATOGR., 1970, Vol 53, pp 171-193.

UDC: 612.172.4.014.421-084

ELECTROCARDIOGRAM IN NEHB TYPE LEADS OF MACACA MULATTA MONKEYS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 3 Dec 84) pp 87-89

[Article by V. P. Melnichenko, M. D. Goldovskaya, I. O. Giryayeva, Yu. V. Shevchenko, G. G. Chamurliyev and V. S. Magedov]

[Text] Macaca mulatta (rhesus) monkeys are used extensively in model experiments, which reproduce various physiological and pathological states, including cardiovascular diseases [6]. There are a considerable number of publications dealing with the normal electrocardiogram (ECG) of lower primates, including Macaca mulatta, which were recorded in standard and amplified monopolar leads from the extremities (I, II, III, aVR, aVL, aVF) and Wilson's monopolar thoracic leads (V_1 -V_6). At the same time, when monitoring the heart's bioelectric activity in chronic experiments there are some advantages to using the system of bipolar precardiac leads of Nehb, since it permits recording the ECG when there is a high signal level in several projection planes of the resultant vector of the heart's electromotive force with a minimum of implanted exploring electrodes. However, there is no information in the literature concerning the standard features of the ECG in the Nehb leads for monkeys. Our objective here was to examine the ECG distinctions of monkeys as recorded in the leads of Nehb using chronically implanted electrodes.

Methods

This study was conducted on clinically healthy male Macaca mulatta monkeys 3-4 years old. The ECG was recorded on an EK4T-02 electrocardiograph using disc electrodes 9 mm in diameter and 0.9 mm in thickness. The electrodes with exploring wires were implanted in the subcuntaenous layers of the chest wall. Their location corresponded to the sites of application of electrodes in the lead system of Nehb [8]: site of attachment of the second right rib to the sternum; dorsal projection of the apex beat on the posterior axillary line; site of maximum apex beat. The ECG was recorded in the dorsal (D), anterior (A) and inferior (I) leads. The electrocardiographic examination was performed no sooner than 2 weeks after implantation of electrodes. Standard ECG characteristics were obtained from analysis of tracings recorded on 17 waking monkeys seated in primatological chairs. We tested the effect of change in position of the body on configuration of the ECG on 7 monkeys anesthetized with ketamine (10 mg/kg intramuscularly). We took the ECG with the animals in three positions: supine, seated and head down.

When there were changes in amplitude of ECG waves related to respiratory excursions, we took into consideration the maximum recorded values.

Results and Discussion

Standard ECG characteristics in Nehb leads. In monkeys seated in primatological chairs, heart rate (HR) constituted a mean of 194/min, with mean duration of PQ, QRS and QT intervals of 0.07, 0.04 and 0.18 s. Figure 1 illustrates samples of ECG tracings recorded in the Nehb leads. Table 1 lists the amplitude characteristics of ECG waves recorded in these leads. The amplitude of the same waves in each lead for each monkey was notable for considerable individual variability. These differences were particularly marked for R and S waves.

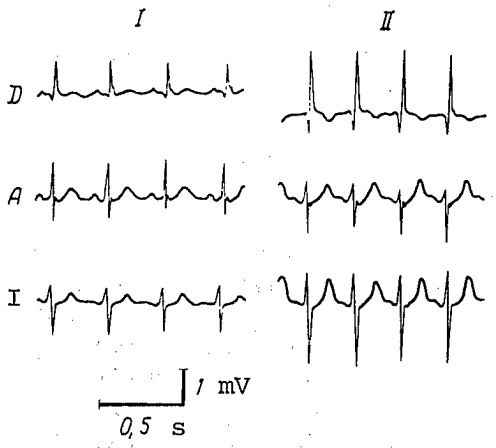


Figure 1.
ECG in Nehb leads for the monkeys, Abrek (I) and Favorit (II)

Thus, the maximum differences in amplitude of R waves in the dorsal and anterior leads reached 1.80 and 1.60 mV, respectively, while those for S waves in anterior and inferior leads, 2.20 and 2.60 mV (see Table 1). It should be noted that the shape of the electrocardiographic tracing remained constant when recordings were repeated.

Analysis of relations between elements of the ECG complex revealed that, in spite of the diversity of variants of the physiological norm, the structure of the ECG curve was characterized by signs that were typical for each lead. According to Table 2, the P wave presented optimum reflection in lead A. Electrical manifestations of excitation of the ventricular myocardium, represented by the Q wave, were most fully reflected in the D lead. The R wave was pronounced in all leads, while the S wave presented maximum expression in the inferior lead of Nehb. The T wave was almost always positive in the anterior and inferior leads. In the dorsal lead, an isoelectric or negative T wave was recorded in over half the animals examined.

Table 1. Amplitude of waves on ECG in Nehb leads (mV), M±m

Lead	ECG waves				
	P	*Q*	*R*	*S*	*T*
D	0,09±0,05 (0,00–0,20)	0,27±0,18 (0,05–0,70)	1,04±0,54 (0,20—2,00)	0,35**	0,03±0,12 (—0,20—0,20)
A	0,11±0,06 (0,05—0,25)	10*	0,86±0,47 (0,30—1,90)	1,10±0,52 (0,20—2,40)	0,41±0,24 (0,00—0,80)
I	0,05±0,05 (0,00—0,20)	0	0,86±0,42 (0,30—1,70)	1,72±0,70 (0,50—3,10)	0,42±0,23 (0,10—0,80)

*Wave was recorded in 2 monkeys **In 3 animals

Note: The range of recorded values is given in parentheses.

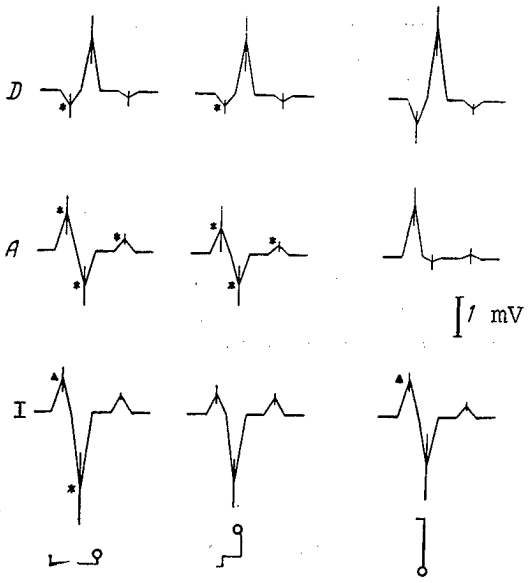


Figure 2.
Positional changes in averaged amplitude characteristics of QRST complex
Dot and vertical line--arithmetic mean and standard deviation (±σ); ★ and ▲ -- P<0.05 in relation to head-down and seated positions, respectively. Level of significance was determined with consideration of interdependence of measured parameters with use of Student's *t* criterion

Upward or downward deflection of ST segment from the isoelectric line did not exceed 0.1 mV. Merely positive shifts of ST were noted in the D lead. In eight monkeys, ST segment was on the isoline in all leads and in the rest, in one or two leads.

Effect of positional factors. We failed to demonstrate appreciable differences in amplitude of P wave in any of the leads in monkeys anesthetized with ketamine, in supine, seated or head-down positions. Changing the monkeys from supine to seated position was not associated with consistent changes in configuration of QRS complex in D and A leads. In the I lead, there was decrease in amplitude of R wave. The amplitude of Q_D and R_A waves was smaller and amplitude of S_A and T_A was greater in animals in seated or supine position than in those put head down. In head-down position, S_I wave was smaller than in supine position (Figure 2).

According to existing data [1], the ECG taken from monopolar thoracic leads of Wilson usually presented a decrease in amplitude of R wave and increase in amplitude of S and T waves when changing monkeys from horizontal to erect position. Analogous postural chnages in R wave were demonstrated in the I lead (see Figure 2).

With reference to our findings, we should stress the marked individual differences in amplitudes of ECG waves observed in the same leads but different animals (see Table 1). The data in the literature indicate that, in Macaca mulatta monkeys, the direction and magnitude of overall electric vector QRS projected on a specific lead plane is characterized by marked individual differences. Thus, in the projection on the frontal plane (standard leads from the extremities), the position of the central electric axis of the heart in clinically healthy monkeys may correspond to a marked dextrogram or levogram [3, 5]. Comparable results had been obtained in vectorcardiographic studies [4].

Ruttkay-Nedecky and Cherkovich [9], who used corrected orthogonal leads, demonstrated in Macaca rhesus monkeys a wide range of ranking of the projection of the integral vector of the QRS complex on the horizontal plane, and maximum deflection of this vector forward or toward the back constituted -126 and +82°, respectively.

Table 2. Variants of ECG's recorded in Nehb leads (number of recorded cases)

Lead	P wave		Start of ventricular complex							T wave		
	P>0	*P=0*	*gR*	*QR*	*gRs*	*gRS*	*rS*	*RS*	*RS*	*T>0*	*T=0*	*T<0*
D	15	2	8	6	2	—	1	—	—	7	6	4
A	17	—	—	—	—	2	—	14	1	16	1	—
I	12	5	—	—	—	—	—	17	—	17	—	—

Note: >0--positive waves, <0--negative waves, =0--waves with amplitude of less than 0.05 mV. Waves in the initial part of the ventricular complex with amplitude equaling or less than 0.2 mV are designated by italic letters and those with more than 0.2 mV amplitude, by upper-case letters.

Thus, the demonstrated distinctions of amplitude characteristics of the ECG in the leads of Nehb supplement existing data concerning the marked individual variability of the ECG of Macaca rhesus monkeys obtained with use of other systems of leads from signals of the heart's electric activity.

On the ECG illustrated, we were impressed by the notches in waves in the last part of the QRS complex (see Figure 1). Such a phenomenon had been observed repeatedly in the examined animals. Re-examinations failed to demonstrate signs of ECG dynamics. There are reports [7] to the effect that, in monopolar thoracic leads, notches in the last part of the QRS complex are observed in 46% of clinically healthy people. The electrogenesis of these notches is related to migration of activation current of the ventricular myocardium or the effect of repolarization of the ventricles.

On the basis of data in the literature and the results of these studies, it can be concluded that, when comparing the standard characteristics of the ECG in the Nehb leads obtained on man [2, 8] and monkeys, one must take into consideration the diveristy of variants of physiologically normal ECG in monkeys, as well as differences between the ECG of lower primates and man, which are manifested in leads that are not only oriented in the frontal plane, but with anteroposterior sagittal orientation [9].

The results of this investigation were taken into consideration in preparing the specifications for an onboard heart rate measuring device for monkeys aboard Cosmos-1514 biosatellite, as well as in selecting ECG leads to monitor animals during spaceflight according to HR: the ECG was recorded in the dorsal lead of Nehb in the monkey, Abrek (see Figure 2) and in the inferior lead of Nehb in Bion. The minimal variability of amplitude of ECG waves with the chosen lead and minimal dependence of recorded signal on postural factors provided for reliable measurement of heart rate during orbital flight.

BIBLIOGRAPHY

1. Belkaniya, G. S., "Funktsionalnaya sistema antigravitatsii" [Functional Antigravity System], Moscow, 1982.

2. Popkov, V. G., in "Voyenno-med. akad. im. S. M. Kirova. Nauch. konf. slushateley. Materialy" [Proceedings of Scientific Conference of Students of the Military Medical Academy imeni S. M. Kirov], Leningrad, 1970, pp 73-74.

3. Atta, A. G. and Vanace, P. W., ANN. N.Y. ACAD. SCI., 1960, Vol 85, pp 811-818.

4. Bristow, S. D. and Malinow, M. R., CIRCULAT. RES., 1965, Vol 16, pp 210-220.

5. Malinow, M. R., FOLIA PRIMATOL., 1966, Vol 4, pp 51-66.

6. Idem, in "The Rhesus Monkey," ed. G. H. Bourne, New York, 1975, Vol 1, pp 77-105.

7. Mirvis, D. M., J. ELECTROCARDIOL., 1983, Vol 16, pp 113-121.

8. Nehb, W., KLIN. WSCHR., 1938, Vol 17, pp 1807-1811.

9. Ruttkay-Nedecky, I. and Cherkovich, G. M., LEK. PRACE, 1977, Vol 14, pp 5-61.

DISCUSSION

UDC: 628.79:612.821

DYNAMICS OF INFORMAL STRUCTURE OF SMALL SPECIAL-PURPOSE GROUP UNDER THE STRESSFUL CONDITIONS OF SOCIAL ISOLATION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (manuscript received 13 Aug 84) pp 90-92

[Article by J. Terelak (Polish People's Republic)]

[Text] The psychology and sociology of small groups that are formed for a special purpose are characterized by the following:

Common motivation or goals that determine the direction of group action.

Presence of a set of standards that determine the guidelines for group action.

Stabilization of group roles.

Establishment of networks of interpersonal relations based on like-dislike attitudes [4].

Every group, particularly one pursuing a special purpose, has its own formal and informal structures ensuing from occupational personality and other differentiations.

The formal structure is based primarily on the hierarchy of power and prestige, which results from performing specific roles and group standards. The relationship between prestige and power determines the difference in social status of group members. The combination of power and prestige produces a high position in the group. The situation where power and prestige diverge is rather interesting to social psychology, which strives to determine the causes of this divergence, in addition to providing a sociometric description of the group. In this situation, it is quite beneficial to investigate the informal structure of a group, which is based on interpersonal relations.

Investigation of the informal sociometric structure on the bases of the sympathy-antipathy criterion clarifies the psychological mechanisms of interpersonal relations. This is particularly important for analysis of effectiveness of action of small special-purpose groups, which are usually characterized by a relatively stable and very simple formal structure (leader or commander and others), but may be quite differentiated with respect to

informal structure [2, 9]. This applies primarily to groups at polar stations and spacecraft crews, which spend considerable time in social isolation.

Investigation of the informal structure of a small special group based on the hierarchy of approval and prestige helps comprehend the phenomenon of social adaptation of its members, as well as the psychological mechanisms of this adjustment. We took as a postulate that the extent of group approval of an individual is a function of both the imposed group standards and interpersonal relations.

Our objective here was to determine the dynamics of informal structure of a small special-purpose group submitted to year-long antarctic isolation.

Methods

These studies were conducted with the participation of 21 people who had spent 1 year in isolation at the Polish Antarctic Station imeni H. Arctowski on King George Island in 1979. The group was characterized by the following formal structure: chief, deputy chief for engineering, research group (9 people) and technical group (10 people). The average age of the group was 34.7 years (28.9 years for the research group and 40.6 years for the technical one).

The group was differentiated according to age (range 24-52 years), education (secondary professional--doctor of sciences), marital status (married and single), social origin (peasants, blue-collar workers, intelligentsia), place of residence (small, medium-sized, large city, village), as well as hierarchy of motivation (financial, scientific, elicited by personal situation, etc.).

This is a typical group for polar expeditions [3, 10]. All this affects the informal structure of the group and the process of social adjustment of its members [6].

The hierarchy of social prestige was determined by the "appointment" method, which is also called the reputation scale [5] and is a modification of the method of Nelson and Gunderson [8], used to form expeditionary groups at small American antarctic stations (Footnote 1) (The appointment method was not approved by members of small groups at many American antarctic stations, since it presented to great a social threat to them [7]). The method consists of having each member of the group list on the reputation scale the four highest and four lowest positions for individuals who were selected according to the following criteria:

Most impressive, least impressive
Is an authority, is not an authority
Most afraid of, least afraid of
Trust the most, trust the least
Want most to collaborate with, want least to collaborate with
Like most to spend free time with, like least to spend free time with
Would like to meet with again in an expedition, would not like to meet with again in an expedition

In addition, we assessed categories such as professional knowledge, industriousness, equilibrium, resistance to frustration, popularity in the group, friendliness, ability for leadership, responsibility.

We determined the hierarchy of prestige twice, at the first and last stages of year-long isolation. The high or low sociometric positions found on this basis were viewed as correlates of social adjustment, the immediate parameter of which was the ratio between number of positive or negative choices.

The positions obtained by different group members on the prestige scale were compared to the evaluations of the chief of the station (formal leader) on the basis of the above-listed criteria. The evaluation was made once at the end of the year of isolation and it was made on a 9-point scale.

The dynamics of the network of interpersonal relations reflecting the hierarchy of approval (sympathy--antipathy) were studied using the method of "vote on goodwill and hostility." This study consisted of having the subjects define their attitude toward the other group members by means of the following scores: ++ like very much, + like, 0 neutral, - do not like, -- strongly dislike. The tests were performed every 2 weeks.

In spite of the variability of social approval inherent in this method, in view of its "game" form (verbal evaluation is a greater social threat for a small isolated group than an assessment using symbols) it was accepted by the subjects.

The evaluation of each subject by all group members on a 5-point scale enabled us to establish their sociometric status on two scales: sympathy and antipathy. The positions on the different scales were calculated on the basis of expansion of the obtained ratings using formulas developed by Pilkiewicz:

For the sympathy scale: SS = (100% ++)+(50%+)
For the antipathy scale SA = (100%--)+(50%-)

Calculation of position on both scales enabled us to distribute each of the subjects in five basic groups on the sociometric scale of approval:

A--approval (A_0--exceptional, A_1--strong, A_2--mild), X--indifference, P--polarity (P_0--exceptional, P_1--strong), I--isolation (I_0--exceptional, I_1--strong, I_2--mild), O--rejection (O_0--exceptional, O_1--strong, O_2--mild)

Approval is a situation in which most group members (or the entire group) approve of someone (emotional component) and appreciate someone (appreciative component).

Isolation is caused by the absence of feedback about the group's evaluation.

Polarity is the effect of absence of unanimity of approval or rejection.

Rejection is determined by negative assessments of the group.

We considered that group approval is an indicator of good social adjustment and that isolation and rejection by the group is, on the contrary, an indicator of nonadjustment. Polarity is an indicator of ambivalence, indicating mainly that there is no integration of the group or that there is a process of disintegration (for example, the situation where there is competition or disapproval of group standards).

The demonstrated dynamics of position on the approval scale (hierarchy of interpersonal attraction) constituted the indicator of social adjustment.

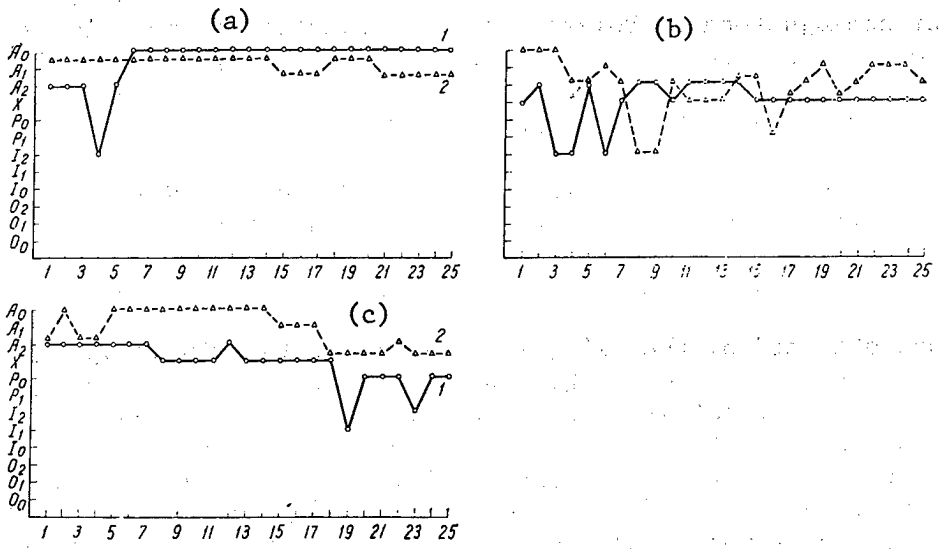
Results and Discussion

The positions obtained by the different members of the wintering group on the prestige scale were compared to the evaluations of the formal leader. We found that there was relative coincidence of group evaluations and those of its leader, primarily with respect to individuals who were best and worst adjusted socially (lowest and highest positions are an indication of this). After the year-long period of isolation, the ranking was particularly high for the electrician (subject 13), physician (2), meteorologist (9) and cook (1). These people enjoyed much authority, mainly because of their competence and necessity on the station. The feeling of safety depended largely on them. The last place of the formal deputy leader (3) in the estimation of the group was a good illustration of the divergence between the position occupied on the power and prestige scale. The third highest position of subject 8 (chemist), who was the informal group leader, indicated that the informal structure of the group is a reflection of a number of mechanisms of social adjustment of interest to a psychologist, particularly in the case of social isolation, which is characterized by absence of many important sources of emotional and social reward.

The position of each subject on the approval scale, as well as dynamics of social adjustment in the 25 successive tests, enabled us to distinguish a certain typology of interpersonal attraction or examples of social adjustment. A "conservative example" of adjustment, which was the most typical of the group we studied, is illustrated in the Figure (a). It is characterized by retention of a relatively stable good place on the approval scale throughout the period of isolation.

A "fluctuating example" of adjustment (subjects 3 and 11) is illustrated in the Figure (b), which is characterized by cyclic changes in positions on the approval scale, in both directions. On the basis of observations, it was found [12] that these were usually individuals who demonstrated their independence of the group and who remained outside the group virtually all of the time (at least, periodically). The "fluctuation example" illustrated in the Figure (b) can be considered in categories of relative social adjustment (subject 11) and nonadjustment (subject 3).

The Figure (c) illustrates a "deadaptation example," which is characterized by insignificant (subject 7) or considerable (subject 5) changes in the direction of diminished attraction. Most often, this is related to decline of prestige (appreciating component) or sympathy (emotional component).



Examples of dynamics of social adjustment in small isolated group
X-axis, sequential number of test; y-axis, approval scale
a) 1 and 2, subjects 16 and 15
b) 1 and 2, subjects 3 and 11
c) 1 and 2, subjects 5 and 7

In summing up the results of these studies of dynamics of interpersonal attraction as an indicator of group adjustment, it should be noted that the method used to study the informal structure of a small isolated special-purpose group has its advantages and drawbacks.

The inconsistency of social approval can be considered a disadvantage of this method (as of all sociometric methods). This applies in essence to studies of a small group submitted to social isolation in both laboratory [1] and natural [11] conditions.

The advantage of this method is its simple game form and feasibility of evaluating individuals by means of symbols. This method can be used to study the informal structure of crews of craft and space stations during long-term flights.

BIBLIOGRAPHY

1. Flin, D. E., Monroe, J. T., Cramer, E. H. et al., AEROSPACE MED., 1961, Vol 32, pp 610-615.

2. Gunderson, E. K. E., "Small Group Structure and Performance in Extreme Environments," (Report No 66-3, U. S. Navy Medical Neuropsychiatric Research Unit), San Diego, California, 1966.

3. Gunderson, E. K. E. and Mahan, J. L., J. PSYCHOL., 1966, Vol 62, pp 287-304.

4. Hare, P. A., "Handbook of Small Group Research," New York, 1962.

5. Mika, S., "Introduction to Group Psychology"[in Polish], Warsaw, 1972.

6. Mullin, C. S. and Connery, H. J., AMER. J. PSYCHIAT., 1960, Vol 117, pp 323-325.

7. Nelson, P. D. and Gunderson, E. K. E., BULL. ET. RECH. PSYCHOL., 1964, Vol 13, pp 111-126.

8. Idem, "Effective Individual Performance in Small Antarctic Stations. A Summary of Criterion Studies," (Report No 63-8, U. S. Navy Medical Neuropsychiatric Research Unit), San Diego, California, 1963.

9. Smith, S. and Haythorn, W., J. PERSON. SOC. PSYCHOL., 1972, Vol 22, pp 67-69.

10. Strange, R. E. and Klein, W. J., in "Polar Human Biology," eds. O. G. Edholm and E. K. Gunderson, London, 1973, pp 410-416.

11. Terelak, J., "Man in Extreme Situations, Antarctic Isolation" [in Polish], Warsaw, 1982.

12. Idem, "Introspection of Antarctica" [in Polish], Warsaw, 1982.

BOOK REVIEW

UDC: 612.89(049.32)

REVIEW OF NOZDRACHEV BOOK ON PHYSIOLOGY OF THE AUTONOMIC NERVOUS SYSTEM

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (signed to press 24 Oct 85) pp 92-93

[Review by Ye. A. Kovalenko of book, "Fiziologiya vegetativnoy nervnoy sistemy" [Physiology of the Autonomic Nervous System], by A. D. Nozdrachev, Leningrad, Meditsina, 1983]

[Text] At the present time, there has been considerable increase in interest of researchers in physiology of the autonomic nervous system. This is attributable primarily to the desire to comprehend the basic mechanisms of control of basic physiological systems of the body in the course of maintaining homeostasis under normal conditions and with exposure to various stressors. The experimental data accumulated to date and the needs of clinicians make it imperative to offer a theoretical generalization and interpretation of the latest advances in this branch of physiology. The surveys in the Soviet literature deal primarily with comprehensive development of various questions of physiology of the autonomic nervous system. In his monograph, A. D. Nozdrachev has made an attempt to discuss the fundamental problems of physiology of the autonomic nervous system as a whole. For this purpose, he analyzes different aspects of structural and functional organization of its sympathetic, parasympathetic and metasympathetic branches.

The monograph is based on a clearcut outline. Comprehensive analysis of branches of the autonomic nervous system is preceded by a chapter entitled "Structure of the Autonomic Reflex Arc," which deals with the main elements of the visceral reflex arc, distinctions of synaptic transmission in the visceral ganglion, as well as higher autonomic centers. Such presentation of the material conforms to a functional approach to the problem. Discussion not only of the main mediators of synaptic transmission in the autonomic nervous system, but endogenous candidates as transmitters, is an important distinction of this chapter. Among the latter, the hormones of the kallikrein-kinin and renin-angiotensin systems are of special interest.

The basic theses of physiology of the sympathetic, parasympathetic and metasympathetic branches of the autonomic nervous system are described following the same outline, which reflects the distinctions of their structural and functional organization. Laying emphasis on the specifics of the branch in question, the author singled out in each of the chapters expressly the particular aspects that enrich the general conception of the autonomic nervous

system as a whole. For example, in the chapter dealing with the sympathetic nervous system, he discusses the distinctions of electric activity of preganglionic and postganglionic neurons and functional differentiation of the latter, which is also inherent in other branches of the autonomic nervous system. There is rather interesting information about synthesis, storage, excretion and inactivation of the main transmitter of the sympathetic nervous system--epinephrine--since they reflect the main patterns of mediator metabolism. Similar sections in the other chapters dealing with metabolism of acetylcholine, serotonin and ATP not only serve as an illustration confirming the previously mentioned basic principles, but emphasize the uniqueness of mediatory conversions in each individual instance. In the section entitled "Sympathectomy," on the example of the sympathetic nervous system, there is discussion of the principal modern methods of excluding (surgical, chemical and immunological) individual structural elements of the autonomic nervous system, which are used extensively in research and clinical practice. The trophic and tonic influence of the sympathetic nervous system is discussed from the vantage point of current knowledge about the mechanisms of neurohormonal influences, which makes it possible to view long-known phenomena at a different angle.

In our opinion, the most interesting chapter is the one about the metasympathetic system, the physiology of which is the subject of the work done by A. D. Nozdrachev and his colleagues. There has been an increase in researchers' interest in this branch of the autonomic nervous system, and this is attributable primarily to the complexity of its functional organization, although its morphological structure seems to be simple. The features in common in the metasympathetic ganglia and structures of the central nervous system with regard to structure, some functions, secretion of a number of neuropeptides, as well as presence of complicated networks that have no equal, which are formed by bundles of axons, harbor mysteries in the metasympathetic system of considerable interest to researchers. Although many of them are far from being resolved, it is growing apparent that the metasympathetic nervous system is a mandatory participant in implementing all vital visceral functions, including homeostasis and heat regulation. Comprehensive analysis of data in the literature and his own material enabled the author to provide an integral conception of the structure, main functions and mechanisms of their implementation in the metasympathetic system. The section dealing with adenosine triphosphoric acid, the transmitter functions of which were first demonstrated expressly in the metasympathetic ganglia, is quite interesting. The results of electrophysiological studies enabled A. D. Nozdrachev to discuss in detail the principles of structural correlations between elements of the metasympathetic system: interneuronal, intra- and extra-ganglionic, as well as extraorganic connections. This served as the basis for development by the author of a scheme of basic organization of elements of the metasympathetic system and description of basic guidelines for modeling neuronal organization. They are also of definite interest in the neurobionic aspect. The author mentions sensory neurons, pacemakers, interneurons, tonic and effector neurons as mandatory elements of an integral functional module. In addition, a minimum number of neural nodes is demonstrable in the module.

In each chapter and, particularly, in the conclusion, we can clearly track the idea of structural and functional interaction of all branches of the

autonomic nervous system, their subordinating and coordinating connections. This helps the reader of the monograph to gain an integral grasp of the function of the autonomic nervous system. The numerous diagrams and illustrations render the basic theses of the book graphic and validated. The original tables furnished in the book are unique in their thoroughness and informative value.

The new information offered in this book about the structural and functional organization of the autonomic nervous system, transmitters of different elements of the autonomic reflex arc, involvement in adaptive reactions have a direct bearing on comprehension of the mechanisms of onset of dysfunctions and development of pathological states.

All of the foregoing enables us to maintain that the monograph of A. D. Nozdrachev is of considerable interest to clinicians and physiologists in the broad sense.

UDC: 613.693:92 Komendantov

OBITUARY OF GEORGIY LEONIDOVICH KOMENDANTOV

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 19, No 6, Nov-Dec 85 (signed to press 24 Oct 85) pp 94-95

[Article by editorial board]

[Text] One of the founders of aviation medicine, Georgiy Leonidovich Komendantov, succumbed suddenly on 24 April 1985, in the 75th year of his life; he was a recipient of the USSR State Prize, doctor of medical sciences, professor, member of the CPSU and active participant in the Great Patriotic War.

G. L. Komendantov began his civic career with service in the Red Army (1931-1937) with the diploma of physician issued by Leningrad Medical Institute.

G. L. Komendantov underwent postgraduate scientific training in the department of physiology of the Military Medical Academy imeni S. M. Kirov under the guidance of Academician L. A. Orbeli. He defended his candidatorial dissertation on the subject of "Physiological Mechanisms of Labyrinthine Reflexes" in 1940, and doctoral dissertation on "Righting Reflexes" in 1964. After completing his postgraduate studies, Georgiy Leonidovich remained as an instructor in the department of physiology.

During the years of the Great Patriotic War, G. L. Komendantov participated in the defense of Leningrad, worked in a surgical clinic, conducted research to solve problems of medical support of military aviation missions.

In the postwar years, G. L. Komendantov was busy as an instructor and in research. He finished his military service in 1960 with the rank of colonel of the medical service.

After G. L. Komendantov was assigned in 1960 as head of the department of aviation medicine at TsOLIUV [Central "Order of Lenin" Institute for Advanced Training of Physicians], the most creative period of his life began. In the last 25 years, more than 30 candidatorial and doctoral dissertations were prepared and defended under his supervision. He established an aviation medicine school of scientists and educators, published more than 30 textbooks on different aspects of aviation medicine totaling 50 printed sheets. In these years, the first volume of his "Selected Lectures on Aviation Medicine" was published, and he prepared a second volume of lectures for publication. Georgiy Leonidovich has authored more than 200 scientific papers dealing with

such questions as pilot rescue in emergency situations, physiological mechanisms of spatial orientation in flight, function of equilibrium under ordinary and extreme conditions, effect of accelerations on man, motion sickness and optimization of postgraduate advanced training of aviation physicians.

G. L. Komendantov was the first to provide a fundamental definition of aviation medicine as a discipline, he developed the subject, tasks and methods of aviation medicine. He was the first in our country to establish a section of aviation medicine for civil aviation.

With his encyclopedic knowledge and great skill as an organizer, Georgiy Leonidovich annually organized symposiums in the department that dealt with pressing problems of aviation medicine. Symposiums on such topics as "Optimization of Instruction of Aviation Medicine," "Means of Improving Instruction on Medical Monitoring," "The Problem of Motion Sickness," "Special Functional Diagnostics," and others were of great scientific importance.

His great scientific exactingness toward himself and his subordinates, along with party-mindedness, sensitivity and benevolence won him much authority among pedagogues, scientists and aviation physicians, both in our country and abroad.

Georgiy Leonidovich was very involved in public service. For many years he was deputy chairman of the section for aviation and space medicine of the Moscow Physiological Society, a member of a specialized council for defense of doctoral dissertations at the Institute of Biomedical Problems, member of the TsOLIUV council and of the medical council of the Ministry of Civil Aviation. He was an ardent propagandist of aviation medicine, and he traveled regularly on behalf of the All-Union Znaniye Society to speak to flight personnel and aviation physicians.

The orders of the Red Banner and Red Star, as well as medals for Combat Services, for Defense of Leningrad, for Victory over Germany in the Great Patriotic War of 1941-1945 and others were bestowed upon G. L. Komendantov for his services to the Homeland.

G. L. Komendantov was an outstanding scientist, brilliant pedagogue, citizen and high-principled communist. He was full of creative plans. He has left behind a school of followers and individuals who shared his ideas, who will continue the work of their teacher and develop theory and practice of aviation medicine.

10657

- END -

CSO: 1849/2